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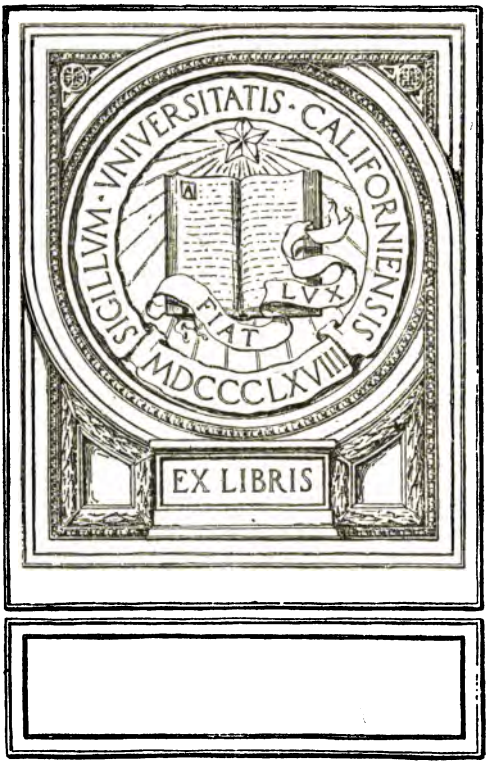
THE WHEAT PROBLEM

BY

SIR W. CROOKES

WITH INTRODUCTION BY LORD RHONDDA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THE WHEAT PROBLEM

THE
WHEAT PROBLEM

Based on Remarks made in the Presidential Address to the British Association at Bristol in 1898

REVISED WITH AN ANSWER TO VARIOUS CRITICS

BY

SIR WILLIAM CROOKES, O.M., F.R.S.

THIRD EDITION

WITH PREFACE AND ADDITIONAL CHAPTER BRINGING THE STATISTICAL INFORMATION UP TO DATE, AND A CHAPTER ON

FUTURE WHEAT SUPPLIES

BY

SIR R. HENRY REW

WITH AN INTRODUCTION BY LORD RHONDDA

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1917

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INTRODUCTION

PARLIAMENT in enacting the Corn Production Act has decided rightly or wrongly that our National policy for some years to come shall be to make our country more self-supporting in the matter of food. The time has therefore come for us to consider the fundamentals of the task which is set before us.

If we grow food, we should grow the best food. Contemporary physiology ratifies the ancient opinion that bread, and above all wheaten bread, is the staff of life. Recent discoveries of "vitamines," or "accessory factors" of diet, merely confirm this opinion when they demonstrate the richness of wheat not only in all the ingredients hitherto recognised as necessary for our support, but also in these newly-identified factors.

Wheat then is the food we should grow, and increased food production really resolves itself into growing more wheat. Now more wheat can be grown in two ways—by increasing the area under that crop or by increasing the yield per acre. The Corn Production Act will increase the wheat area. It is the part of science to increase the yield.

Much has been done already in this direction. The work of Professor R. H. Biffen and the Cambridge School of Agriculture based upon the Mendelian conception of heredity, which was demonstrated in this country by Professor William Bateson, has resulted in the production of new

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varieties of wheat which yield 10 per cent. more grain per acre than other varieties and possess also the excellent milling and baking qualities of the highest grade wheat from Canada and the United States.

Furthermore, the work of the Rothamsted Experimental Station, founded by Sir John Lawes and directed by the late Sir Henry Gilbert and more recently by Mr. A. D. Hall and his successor, Dr. E. J. Russell, has demonstrated that the prime factor in wheat production is a sufficient supply of nitrogenous manure. Yields of wheat exceeding the national average have been reaped from certain of the Rothamsted plots continuously every year for eighty years by judicious cultivation and manuring, and there is at least one instance in this country of successful continuous wheat-growing on the farming scale on Rothamsted lines. Experience gained during the war has further shown that fine crops of cereals can be grown by suitable manuring on newly broken up grassland without the expense of growing preparatory non-cereal crops. Obviously, the accepted views as to rotation of crops stand in need of revision.

Another point which has for years gained universal acceptance in agricultural circles—the view that livestock with its by-product farmyard manure is the backbone of wheat production—is also in the melting pot. Farmers are far too prone to regard farmyard manure—that variable mixture of unknown chemical compounds, bacteria and protozoa —as the panacea of all the ills that soils are heir to. It is true that farmyard manure supplies a quantity of nitrogenous food to the plant which should be

zealously preserved for manurial purposes, but it is also true that on the average half of this is lost by the rough and ready methods of preservation practicable on the farm. It must not be forgotten, too, that farmyard manure supplies humus to the soil without which permanent fertility is difficult to maintain. But in spite of these considerations, it cannot be denied that a greatly increased home production of nitrogenous manure is indispensable if the home production of wheat is to be increased to anything like the extent required to make the country self-supporting.

The value of fixed nitrogen in the form of Chilian Nitrates has long been known. Longer still have the chemists known that our atmosphere is mostly nitrogen and that this element can be fixed or combined with other elements by certain means—as by lightning, for instance. Man may command Nature by obeying her, in Bacon's phrase, and imitate the electric process. The electrical production of nitrates is now many years old.

The fixation of the atmospheric nitrogen is suggested by the chemist as his contribution to the maintenance and extension of the civilisations which depend upon wheat.

Such was Sir William Crookes's argument in the last decade of the nineteenth century. The time has now come when it is urgently necessary for us to avail ourselves of this gift from knowledge.

In Southern Norway, for years past, atmospheric nitrogen has been fixed to feed cereals. In Germany, especially since the War, our blockade having cut off the supply of Chilian Nitrates, nitrogen has been fixed by a more recent method, for food and for explosives.

Foreseeing the very plight in which his country, thanks to its aggression and our Navy, now is, the German chemist, Ostwald, devoted himself a few years ago to the practical development of nitrates from ammonia, and to the catalytic production of that compound from its constituent elements, nitrogen and hydrogen.[1] Some very small beginning has lately been made in this country with the employment of Ostwald's method. The production of synthetic ammonia depends in no degree upon a cheap supply of electricity. It is as feasible in this country, therefore, as in Southern Norway, and deprives us of our last excuse for our long neglect of this subject. Alike for agriculture, explosives, and dyes, synthetic ammonia is the beginning—and it is ours in any quantity for the making.

In the United States an immense scheme for the purpose is now afoot. In the country of the great chemist whose Presidential Address to the British Association roused all thoughtful minds nineteen years ago, comparatively little has been done. At the present time, there is in this country a shortage of artificial fertilisers, chiefly because there is a shortage of freight space. The nitrates are in abundance in Chili, but we need them here and shall increasingly need them.

The extent to which farmers in this country rely solely on farmyard manure is an instance of their conservatism or ignorance of modern developments in agricultural knowledge. The effect has lately been demonstrated by Mr. T. H. Middleton in a report for the Board of Agriculture, in which

[1] See "Chemistry in the Service of Man," by Professor Alexander Findlay, Second Edition, 1917, pp. 123–129. (Longmans, Green & Co).

he shows that, starting far behind in the race a generation ago, the German farmer now produces much more food per acre than the British, though he has a poorer soil and climate.

Farmers will ask what is to become of the enormously increased quantity of straw which will result from doubling or trebling the present corn area. It cannot be made into farmyard manure on present lines without doubling or trebling the livestock of the country, and that is impracticable, for we are already self-supporting as regards milk, we already produce two-thirds of the meat we consume, and the horse population is likely to decrease further as the use of motors increases.

Fortunately, there are other outlets for straw. A large quantity can be profitably disposed of for making straw board and the coarser kinds of paper, and if this does not suffice, it is by no means impossible that processes may be worked out which will make it practicable to convert straw into good fertilising material by the direct agency of bacteria without the assistance of animals.

In such circumstances, Sir William Crookes has revised and largely re-written his book. In this new edition he has considered not merely the recent statistics of wheat production, but also the judgments contained in certain of the valuable publications which we owe to the United States. The thoughtful American reader will do well to recognise in the following pages much that concerns him, scarcely less than it concerns ourselves. In the fixation of atmospheric nitrogen both Britain and the United States are laggards for whom it is difficult to find excuse.

The attention which can scarcely fail to be directed to this subject by Sir William Crookes's treatise ought now to result in the action which we should have taken a decade ago. We lacked nothing but the foresight and the will; we had the knowledge, we had the power, if not in falling water then in coal. To-day no foresight is required to recognise the need, and necessity is spurring our will. If we are to feed ourselves, we must begin by securing a continual provision of the fixed nitrogen which is necessary to feed our best food, and which we can begin to make for ourselves, in any quantities, whenever we please.

The present edition includes a chapter on our Future Wheat Supplies, written at my suggestion by my friend Sir Henry Rew. This chapter contains valuable information on the wheat production of the world and is a fitting conclusion to the book.

My attention was first directed to Sir William Crookes's book, and to the fact that it was all too little known, by an article published by Dr. C. W. Saleeby in July, 1915, and it was a pleasure then to undertake the financial responsibility for the revision and republication. That pleasure is not lessened now when the work appears and finds me as Food Controller occupying a post in relation to the Nation's food which probably no one could have foreseen when the present revision was undertaken. I shall count myself well rewarded if the re-issue of this book may help to increase the production of food within our own shores and so render more secure our national existence.

LONDON, RHONDDA.

November, 1917.

PREFACE TO THE FIRST EDITION

THE present volume arises out of the comments and criticisms provoked by the Address I delivered before the Members of the British Association in September 1898. There were difficulties in the presentation of my subject. Limited to little more than an hour, I was compelled, from consideration to my audience, to deal with the results of study rather than with details leading to such results. And constrained by respect for my responsible position to treat the matter soberly and without exaggeration, it was impossible for me to do more than barely outline the serious peril awaiting wheat-eaters who contentedly pursue the present wasteful system of cultivation. My remarks took the form of a warning rather than of a prophecy. To put the matter briefly, I stated that under present conditions of heedless culture, a scarcity of wheat is within appreciable distance; that wheat-growing land all over the world is becoming exhausted, and that at some future time—in my opinion not far distant—no available wheat land will be left. But I also pointed out that Nature's resources, properly utilised, are ample. I urged

that, instead of being satisfied with an average world-yield of 12·7 bushels an acre, a moderate dressing of chemical manure would pull up the average to 20 bushels—thus postponing the day of dearth " to so distant a period that we and our sons and grandsons may legitimately live without undue solicitude for the future."

It was far from my intention to create a sensation, or to indulge in a " cosmic scare." After considerable study, I placed before the public hard and formidable *facts*. I have been assailed with criticism—unfavourable, abusive, suggestive—but, having pondered disputed points, I cannot in any material degree modify my estimates of the future producing capacity of the wheat fields of the globe.

In preparing this volume, I have endeavoured to give in greater fulness the data on which my conclusions are based. The actual and potential wheat-producing capacity of the United States is—and will be for years to come—the dominant factor in the world's bread supply. I therefore give prominence to criticisms launched against me in refutation of the intrinsic part of my argument. I have had invaluable assistance from Mr. Wood Davis, of Peotone, Kansas, a wheat grower and statistician of recognised authority. Mr. Davis appears to be the sole person who deals with the problem in a manner to determine such essential factors as average acre yields for long periods, unit requirements for each of the primary food staples of the temperate zones, and the ratios existing during different recent periods between the consuming

populations and the acres employed in the production of each of the primary food staples. Mr. Davis has contributed to this volume a chapter in which he goes over the whole ground, and practically corroborates all my statements.

I am also permitted to include in my volume, by the kindness of the proprietors of the *North American Review*, an article written by the Honble. John Hyde, Chief Statistician to the Agricultural Department of the United States, in which the wheat problem is discussed with especial reference to the future food supply of the States. In an appendix I include still later figures received from Mr. Hyde.

I have no wish to be gloomy, and certainly no wish to consider myself infallible. If at the end of another generation of wasteful culture my forecast is invalidated by the *Unforeseen*, I cheerfully invite friends and critics to stone me as a false prophet.

WILLIAM CROOKES.

July, 1899.

PREFACE TO THE PRESENT EDITION

In preparing a new Edition of this work I have deemed it best to repeat in full my Address delivered before the meeting of the British Association for the Advancement of Science in 1898. The articles by Mr. C. Wood Davis and the Hon. John Hyde have been omitted and their place taken by an important contribution from Sir H. Rew on "The Future of Wheat Supplies," while I have added some further matter on the present aspects of the Wheat Problem, and also have brought many of the statistics up to date, and discussed some subjects more fully than was possible at the time of the original Address. Since that date the fixation of atmospheric nitrogen has been carried out on a commercial scale, and much useful work has been done upon the improvement and cultivation of wheat —and meanwhile the growth of the wheat crop in England has shown a steady decline, the serious aspect of which has been almost unrecognised by the public at large. The outcome of the attitude of our leaders and of the Nation towards agriculture is accentuating the present crisis in our food supply and it is in the belief that no means should be neglected

to demonstrate the importance of the question and the danger of taking half-measures now and trusting to the future to look after itself, that I have felt it my duty once more to state the wheat problem and to put my conclusions before the public. Various suggestions have been made to remedy the state of agriculture in England, such as the establishment of industrialised farms and the extension of the system of co-operative small holdings, but it does not lie within the scope of this work to discuss such proposals in detail. As far as pure science is concerned, it is well to keep constantly in view the very great deviation of the average yield of wheat per acre from the highest attained, and the problem before the scientific man is to learn how to control the yield so that the average may be steadily raised. Perhaps the most disquieting feature of the whole question of the world's wheat supply is the very poor increase of yield which has been effected in the last twenty years, and it is to this fact that I wish to direct attention, as well as to the decline of wheat-growing in England.

WILLIAM CROOKES.

UNIV. OF
CALIFORNIA

THE WHEAT PROBLEM[1]

I

STATEMENT OF THE PROBLEM

FOR the third time in its history the British Association meets in your City of Bristol. The first meeting was held under the presidency of the Marquis of Lansdowne in 1836, the second under the presidency of Sir John Hawkshaw in 1875. Formerly the President unrolled to the meeting a panorama of the year's progress in physical and biological sciences. To-day, the President usually restricts himself to specialities connected with his own work, or deals with questions which, for the time, are uppermost. To be President of the British Association is undoubtedly a great honour. It is also a great opportunity and a great responsibility; for I know that, on the wings of the Press, my words, be they worthy or not, will be carried to all points of the compass. I propose to deal with

[1] This forms the major portion of my Presidential Address, delivered before the British Association for the Advancement of Science, at Bristol, on the evening of 7th September, 1898. The only alterations I have made are the corrections of one or two minor inaccuracies, and the incorporation of the matter originally consigned to an Appendix into the body of the Address.

the important question of the supply of bread to the inhabitants of these islands. I shall not attempt any general survey of the sciences; these, so far as the progress in them demands attention, will be more fitly brought before you in the different Sections, either in the Addresses of the Presidents or in communications from Members.

And now I owe a sort of apology to this brilliant audience. I must ask you to bear with me for ten minutes, for I am afraid what I now have to say will prove somewhat dull. I ought to propitiate you, for, to tell the truth, I am bound to bore you with figures. Statistics are rarely attractive to a listening audience; but they are necessary evils, and those of this evening are unusually doleful. Nevertheless, when we have proceeded a little way on our journey I hope you will see that the river of figures is not hopelessly dreary. The stream leads into an almost unexplored region, and to the right and left we see channels opening out, all worthy of exploration, and promising a rich reward to the statistic explorer who will trace them to their source —a harvest, as Huxley expresses it, "immediately convertible into those things which the most sordidly practical of men will admit to have value, namely, money and life." My chief subject is of interest to the whole world—to every race—to every human being. It is of urgent importance to-day, and it is a life and death question for generations to come. I mean the question of Food supply. Many of my statements you may think are of the alarmist order; certainly they are depressing, but they are

founded on stubborn facts. They show that England and all civilised nations stand in deadly peril of not having enough to eat. As mouths multiply, food resources dwindle. Land is a limited quantity, and the land that will grow wheat is absolutely dependent on difficult and capricious natural phenomena. I am constrained to show that our wheat-producing soil is totally unequal to the strain put upon it. After wearying you with a survey of the universal dearth to be expected, I hope to point a way out of the colossal dilemma. It is the chemist who must come to the rescue of the threatened communities. It is through the laboratory that starvation may ultimately be turned into plenty.

The food supply of the kingdom is of peculiar interest to this meeting, considering that the grain trade has always been, and still is, an important feature in the imports of Bristol. The imports of grain to this city amount to about 25,000,000 bushels per annum—8,000,000 of which consist of wheat.

What are our home requirements in the way of wheat? The consumption of wheat per head of the population (unit consumption) is over 6 bushels per annum; and taking the population at 40,000,000, we require no less than 240,000,000 bushels of wheat, increasing annually by 2,000,000 bushels, to supply the increase of population. Of the total amount of wheat consumed in the United Kingdom we grow 25 and import 75 per cent.

So important is the question of wheat supply that it has attracted the attention of Parliament,

and the question of national granaries has been mooted. It is certain that, in case of war with any of the great Powers, wheat would be contraband, as if it were cannon or powder, liable to capture even under a neutral flag. We must therefore accept the situation, and treat wheat as munitions of war, and grow, accumulate, or store it as such. It has been shown that at the best our stock of wheat and flour amounts only to 64,000,000 bushels—fourteen weeks' supply—while last April our stock was equal to only 10,000,000 bushels, the smallest ever recorded by *Beerbohm* for the period of the season. Similarly, the stocks held in Europe, the United States, and Canada, called "the world's visible supply," amounted to only 54,000,000 bushels, or 10,000,000 less than last year's sum total, and nearly 82,000,000 less than that of 1893 or 1894 at the corresponding period. To arrest this impending danger, it has been proposed that an amount of 64,000,000 bushels of wheat should be purchased by the State, and stored in national granaries, not to be opened except to remedy deterioration of grain, or in view of national disaster rendering starvation imminent. This 64,000,000 bushels would add another fourteen weeks' life to the population; assuming that the ordinary stock had not been drawn on, the wheat in the country would only then be enough to feed the population for twenty-eight weeks.

I do not venture to speak authoritatively on national granaries. The subject has been discussed in the daily Press, and the recently published Report from the Agricultural Committee on National Wheat

Stores brings together all the arguments in favour of this important scheme, together with the difficulties to be faced if it be carried out with necessary completeness.

More hopeful, although difficult and costly, would be the alternative of growing most, if not all, our own wheat supply here at home in the British Isles. The average yield over the United Kingdom last year was 29·07 bushels per acre, the average for the last eleven years being 29·46. For twelve months we need 240,000,000 bushels of wheat, requiring about 8,250,000 acres of good wheat-growing land, or nearly 13,000 square miles, increasing at the rate of 100 square miles per annum, to render us self-supporting as to bread food. This area is about one-fourth the size of England.

Last year there were under corn crops in the United Kingdom :—

Wheat	3,025 sq. miles,	producing 56,296,000 bushels.
Barley	3,447 ,,	
Oats	6,580 ,,	
TOTAL	13,052 ,,	

There is now as much area under mixed cereals as would have to be devoted solely to wheat to make our country self-supporting.

A total area of land in the United Kingdom equal to a plot 110 miles square, of quality and climate sufficient to grow wheat to the extent of 29 bushels per acre, does not seem a hopeless demand.[1] It is doubtful, however, if this amount

[1] The total area of the United Kingdom is 120,979 square miles; therefore the required land is about a tenth part of the total.

of land could be kept under wheat, and the necessary expense of high farming faced, except under the imperious pressure of impending starvation, or the stimulus of a national subsidy or permanent high prices. Certainly these 13,000 square miles would not be available under ordinary economic conditions, for much, perhaps all, the land now under barley and oats would not be suitable for wheat. In any case, owing to our cold, damp climate and capricious weather, the wheat crop is hazardous, and for the present our annual deficit of 180,000,000 bushels must be imported. A permanently higher price for wheat is, I fear, a calamity that ere long must be faced. At enhanced prices, land now under wheat will be better farmed, and therefore will yield better, thus giving increased production without increased area.

The burning question of to-day is, What can the United Kingdom do to be reasonably safe from starvation in presence of two successive failures of the world's wheat harvest, or against a hostile combination of European nations? We eagerly spend millions to protect our coasts and commerce; and millions more on ships, explosives, guns, and men; but we omit to take necessary precautions to supply ourselves with the very first and supremely important munition of war—food.

To take up the question of food supply in its scientific aspect, I must not confine myself exclusively to our own national requirements. The problem is not restricted to the British Isles—the bread-eaters of the whole world share the perilous prospect—and

I do not think it out of place if, on this occasion, I ask you to take with me a wide, general survey of the wheat supply of the whole world.

Wheat is the most sustaining food grain of the great Caucasian race which includes the peoples of Europe, United States, British America, the white inhabitants of South Africa, Australasia, parts of South America, and the white population of the European colonies. Of late years the individual consumption of wheat has almost universally increased. In Scandinavia it has risen 100 per cent. in twenty-five years; in Austria-Hungary, 80 per cent.; in France, 20 per cent.; while in Belgium it has increased 50 per cent. Only in Russia and Italy, and possibly Turkey, has the consumption of wheat per head declined.

In 1871 the bread-eaters of the world numbered 371,000,000. In 1881 the numbers rose to 416,000,000; in 1891, to 472,600,000, and at the present time they number 516,500,000. The augmentation of the world's bread-eating population in a geometrical ratio is evidenced by the fact that the yearly aggregates grow progressively larger. In the early 'seventies they rose 4,300,000 per annum, while in the 'eighties they increased by more than 6,000,000 per annum, necessitating annual additions to the bread supply nearly one-half greater than sufficed twenty-five years ago.

How much wheat will be required to supply all these hungry mouths with bread? At the present moment it is not possible to get accurate estimates of this year's wheat crops of the world, but an

adequate idea may be gained from the realised crops of some countries and the promise of others. To supply 516,500,000 bread-eaters, if each bread-eating unit is to have his usual ration, will require a total of 2,324,000,000 bushels for seed and food. What are our prospects of obtaining this amount?

According to the best authorities, the total supplies from the 1897–98 harvest are 1,921,000,000 bushels. The requirements of the 516,500,000 bread-eaters for seed and food are 2,324,000,000 bushels; there is thus a deficit of 403,000,000 bushels, which has not been urgently apparent

TABLE I.

The World's Wheat Crop of 1897–98 from Contributory Areas.[1]

	BUSHELS		BUSHELS
United States	510,000,000	Uruguay, Brazil, etc.	9,000,000
France	240,000,000	Portugal	7,000,000
Russia and Poland	230,000,000	Servia	6,000,000
Austria-Hungary	135,000,000	Holland	5,000,000
Germany	105,000,000	Denmark	5,000,000
Spain	96,000,000	Sweden and Norway	5,000,000
Italy	82,000,000	Greece	4,000,000
Trans-Caucasia and Siberia	64,000,000	Switzerland	4,000,000
Argentina	60,000,000	Bosnia, Montenegro, Cyprus, etc.	4,000,000
United Kingdom	56,000,000	South Africa	4,000,000
Canada	55,000,000		1,890,000,000
Roumania	43,000,000		
Caucasia (Northern)	40,000,000	Add imports from Asia and North Africa	31,000,000
Australasia	38,000,000		
Bulgaria	30,000,000		
Turkey in Europe	22,000,000		
Belgium	16,000,000	Total available wheat supply	1,921,000,000
Chili	15,000,000		

[1] Outside the better known areas of wheat supply a certain proportion of wheat comes from India, Persia, Syria, Anatolia, and North Africa. But it is impossible to get accurate figures as to acreage and yield from these countries; as bread-eaters derive less than one per cent. of their supplies from these outlying sources, it is convenient to call the ordinary areas "contributory areas," and to deal with the external areas no further than to show the volume of imports yielded from year to year.

TABLE II.

Table showing the Variations in the Bread-eating Populations, and the Available Supply of Wheat in the Five Yearly Periods from 1878 to 1897, in Millions of Bushels, and Annual Averages.

YEARS.	Bread-eating Population.	Wheat grown by 'Contributory areas.'	Imports from Asia and North Africa.	Remainders from former harvest.	Total available supply.	Required for seed and food.	Supply in excess of year's needs.
1877–81	407·0	1797·0	13·8	174·4	1985·2	1812·8	172·4
1882–86	432·8	1937·6	41·4	294·0	2273·0	1946·0	327·0
1887–91	460·8	2043·5	43·2	260·2	2346·9	2102·0	244·9
1892–96	490·9	2199·2	23·6	265·4	2488·2	2233·8	254·4
1897–98	510·0	1890·0	31·0	300·0	2221·0	2310·0	Deficit 89·0

owing to a surplus of 300,000,000 bushels carried over from the last harvest. Respecting the prospects of the harvest year just beginning, it must be borne in mind that there are no remainders to bring over from last harvest. We start with a deficit of 103,000,000 bushels, and have 6,500,000 more mouths to feed. It follows, therefore, that one-sixth of the required bread will be lacking unless larger drafts than now seem possible can be made upon early produce from the next harvest.

The import requirements for wheat are as follows :—

TABLE III.

	BUSHELS		BUSHELS
United Kingdom, about	180,000,000	Spain	10,000,000
Belgium	24,000,000	Portugal	4,000,000
Germany	35,000,000	Greece	4,500,000
Holland	13,000,000	Denmark	2,000,000
Switzerland	13,500,000	Islands and tropical lands	42,000,000
France	40,000,000		
Sweden	4,000,000	TOTAL	372,000,000

The majority of the wheat crops between 1882

and 1896 were in excess of current needs, and thus considerable reserves of wheat were available for supplementing small deficits from the four deficient harvests. But bread-eaters have almost eaten up the reserves of wheat, and the 1897 harvest being under average, the conditions become serious.

Between 1882 and 1897 the wheat crops were so abundant that over 1,200,000,000 bushels were added to our stores, beside large accumulations of rye. During this time of golden harvests, the exports from Russia increased, in consequence of the Russian decline in unit consumption of 13·5 per cent. These reserves have been gradually drawn upon, but enough still remained to obscure the fact that the 1895–96 harvest was 75,000,000 bushels, and the 1896–97 harvest was 138,000,000 bushels below current needs.

The following table has been compiled from statistics carefully collected by Mr. Davis and other observers.[1] The prophetic figures are on

[1] I have taken the unit consumption including seed at 4·5 bushels and the yield per acre at 12·7 bushels per annum, this being the average of the whole world. The exact yield varies with the country in which wheat is grown, as shown by the following table :—

TABLE IV.

Average Yield of Wheat per Acre in—

	BUSHELS		BUSHELS
Denmark	41·8	Poland	16·2
United Kingdom	29·1	Canada	15·5
New Zealand	25·5	Argentina	13·0
Norway	25·1	Italy	12·1
Germany	23·2	United States (mean)	12·0
Belgium	21·5	Australasia	10·0
Holland	21·5	India	9·2
France	19·4	Russia in Europe	8·6
Hungary	18·6	Algeria	7·5
Roumania	18·5	South Australia	7·0
Austria	16·3		

the assumption that population, unit consumption, and steady development will increase during the next forty-three years as they have increased since 1871 :—

TABLE V.

Date	Bread-eaters	Food and Seed [1] required per unit. Bushels	Requiring bushels of wheat	With yields averaging 12·7 bushels acreage required
1871	371,000,000	4·15	1,540,000,000	121,000,000
1881	416,000,000	4·38	1,822,000,000	143,000,000
1891	472,600,000	4·50	2,127,000,000	167,000,000
1898	516,500,000	4·50	2,324,000,000	183,000,000
1901	536,100,000	4·50	2,412,000,000	190,000,000
1911	603,700,000	4·50	2,717,000,000	214,000,000
1921	674,000,000	4·50	3,033,000,000	239,000,000
1931	746,100,000	4·50	3,357,000,000	264,000,000
1941	819,200,000	4·50	3,686,000,000	290,000,000

[1] The seed quota is kept constant at 0·6 bushel per unit per annum, but the unit food requirements are found to increase in each five-yearly period. There has been a steady increase of unit wheat requirements by reason of the decrease of unit consumption of rye, maslin, spelt, and buckwheat.

To supply these bread-eaters, the world inhabited by bread-eating populations grew the following quantities of wheat in each of the designated five-year periods :—

TABLE VI.

Years	Bushels—Annual average	Acres—Annual average
1871–75	1,580,000,000, grown on	131,000,000
1876–80	1,746,000,000 ,,	143,000,000
1881–85	1,926,000,000 ,,	152,000,000
1886–90	1,987,000,000 ,,	154,000,000
1891–95	2,201,000,000 ,,	159,000,000

Within the same periods wheat was imported

from Asia and North Africa by the "bread-eating" countries as follows:—

TABLE VII.

Years	Bushels—Annual average	Acres—Annual average
1871–75	8,000,000, the net product of	750,000
1876–80	12,000,000 ,, ,,	1,120,000
1881–85	36,000,000 ,, ,,	3,360,000
1886–90	39,000,000 ,, ,,	3,640,000
1891–95	34,000,000 ,, ,,	3,200,000

Broadly speaking, 2,000,000,000 bushels are now consumed in the countries where they are grown, either as food or for seed, while the balance is exported.

That scarcity and high prices have not prevailed in recent years is due to the fact that since 1889 we have had seven world crops of wheat and six of rye abundantly in excess of the average. These generous crops increased accumulations to such an extent as to obscure the fact that the harvests of 1895 and 1896 were each much below current requirements. Practically speaking, reserves are now exhausted, and bread-eaters must be fed from current harvests—accumulation under present conditions being almost impossible. This is obvious from the fact that a harvest equal to that of 1894 (the greatest crop on record, both in acre-yield and in the aggregate) would yield less than current needs.

At the present time the disproportion is even higher, owing to unit consumption gradually in-

creasing from year to year, accompanied by slow shrinkage in the wheat area.

TABLE VIII.

—	1871	1884	1897	Per cent. of increase or decrease in twenty-six years
Population	371,000,000	432,800,000	510,000,000	37·5 increase
Wheat acres	125,800,000	154,300,000	158,000,000	25·6 increase
Rye acres	111,000,000	110,300,000	106,500,000	4·1 decrease

The area planted with the two great bread-making grains is actually less now than thirteen years ago, despite enormous additions to the population. The area under *all* the bread-making grains is absolutely 2·2 per cent. less than thirteen years ago, notwithstanding an increase of one-fifth in requirements for bread.

It is clear we are confronted with a colossal problem that must tax the wits of the wisest. When the bread-eaters have exhausted all possible supplies from the 1897–98 harvest, there will be a deficit of 103,000,000 bushels of wheat, with no substitution possible unless Europeans can be induced to eat Indian corn or rye bread. Up to recent years the growth of wheat has kept pace with demands. As wheat-eaters increased the acreage under wheat expanded. The world has become so familiarised with the orderly sequence of demand and supply, so accustomed to look upon the vast plains of other wheat-growing countries as inexhaustible granaries, that, in a light-hearted way, it is taken for granted that so many million additional acres can be added

year after year to the wheat-growing area of the world. We forget that the wheat-growing area is of strictly limited extent, and that a few million acres regularly absorbed soon mount to a formidable number.

The present position being so gloomy, let us consider future prospects. What are the capabilities as regards available area, economic conditions, and acreage yield of the wheat-growing countries whence we now draw our supply?

For the last thirty years the United States have been the dominant factor in the foreign supply of wheat, exporting no less than 145,000,000 bushels. This shows how the bread-eating world has depended, and still depends, on the United States for the means of subsistence. The entire world's contributions to the food-bearing area have averaged but 4,000,000 acres yearly since 1869. It is scarcely possible that such an average, under existing conditions, can be doubled for the coming twenty-five years.

Notwithstanding this expansion, the supplies of wheat were hardly sufficient for the food demands of the world. As the area under wheat has increased, that under rye has diminished, with the result that scarcely an acre has been added to the world's wheat and rye since 1890; and there was in 1897 a deficit in the two principal bread-making grains of more than 600,000,000 bushels.

Almost yearly since 1885 additions to the wheat-growing area have diminished, while the requirements of the increasing population of the States

have advanced, so that the needed American supplies have been drawn from the acreage hitherto used for exportation. Practically there remains no uncultivated prairie land in the United States suitable for wheat-growing. The virgin land has been rapidly absorbed, until at present there is no land left for wheat without reducing the area for maize, hay, and other necessary crops.

Stocks of wheat and flour in the United States were, relatively to population, probably never smaller, if so small as now. The following table (from *Bradstreet*) shows the visible supply of wheat in the States on 1st June since 1893 :—

TABLE IX.

	BUSHELS		BUSHELS
1893 . .	. 93,700,000	1896 . .	. 71,300,000
1894 . .	. 80,500,000	1897 . .	. 39,200,000
1895 . .	. 72,800,000	1898 . .	. 32,500,000

It is almost certain that within a generation the ever increasing population of the United States will consume all the wheat grown within its borders, and will be driven to import, and, like ourselves, will scramble for a lion's share of the wheat crop of the world. This being the outlook, exports of wheat from the United States are only of present interest, and will gradually diminish to a vanishing point. The inquiry may be restricted to such countries as probably will continue to feed bread-eaters who annually derive a considerable part of their wheat from extraneous sources.[1]

But if the United States, which grow about one-

[1] *See* Note, p. 8.

fifth of the world's wheat, and contribute one-third of all wheat exportations, are even now dropping out of the race, and likely soon to enter the list of wheat-importing countries, what prospect is there that other wheat-growing countries will be able to fill the gap, and, by enlarging their acreage under wheat, replace the supply which the States have so long contributed to the world's food? The withdrawal of 145,000,000 bushels will cause a serious gap in the food supply of wheat-importing countries, and unless this deficit can be met by increased supplies from other countries there will be a dearth for the rest of the world after the British Isles are sufficiently supplied.

Next to the United States, Russia is the greatest wheat exporter, supplying nearly 95,000,000 bushels. In 1896 the area under wheat in the Governments of Russia and Poland was 36,000,000 acres. But the yearly consumption of wheat per head during the last ten years has declined 14 per cent., and the consumption of bread is quite 30 per cent. less than is required to keep the population in health. The grain reserved for seed has likewise decreased—the peasantry limiting their sowing with the rise of taxation. The reduction of 14 per cent. in the unit consumption of bread in Russia has added, during the last eighteen years, 1,360,000,000 bushels to the general wheat supply. This factitious excess temporarily staved off scarcity in Europe.

Although Russia at present exports so lavishly, this excess is merely provisional and precarious. The Russian peasant population increases more

rapidly than any other in Europe. The yield per acre over European Russia is meagre—not more than 8·6 bushels to the acre—while some authorities consider it as low as 4·6 bushels. The cost of production is low—lower even than on the virgin soils of the United States. The development of the fertile though somewhat overrated "black earth," which extends across the southern portion of the empire, and beyond the Ural Mountains into Siberia, progresses rapidly. But, as we have indicated, the consumption of bread in Russia has been reduced to danger point. The peasants starve, and fall victims to "hunger typhus," whilst the wheat growers export grain that ought to be consumed at home.[1]

[1] This was written in the summer of 1898. What the situation is in Russia twelve months later may be judged from the following description sent from Moscow, under date 22nd May, and published in *The Globe* for 26th May, 1899:—

"THE FAMINE IN RUSSIA.

"The Russian public has at last awoke to the fact that there really is a famine in the land, and money is beginning to flow in from all sides for the relief of the starving moujiks. The aristocracy is particularly generous in making donations, and this may perhaps be ascribed to its former connection with the peasants, their old serfs. Unfortunately, this sudden outbreak of charity comes all too late. Even so far back as last autumn one of the leading journals of St. Petersburg drew attention to the fact that there would be a great famine, and described even then the terrible condition of the peasantry. As the journal in question was rebuked by the Censor, and partially suppressed for taking the trouble to speak the truth, few papers dared to devote much space to the approaching famine. Some papers utterly ignored it, and, after reading the leading newspapers of Russia, one remained in happy ignorance of the gaunt spectre of famine already stalking through the land, and claiming its thousands and tens of thousands of victims. At last, when the winter was well-nigh past, the Press summoned up courage, and began to speak in a vague manner of the failure of the crops in certain parts of Russia, and allusion was made to the consequent starvation of the people. But this information came too late, and thousands are now no more whose lives might

Considering Siberia as a wheat grower, climate is the first consideration. Summers are short—as

have been spared had the full truth of this awful calamity been published in the autumn instead of towards the close of the winter.

"As the outside world is still unaware of the enormous extent of this famine, and of the terrible sufferings of the famine-stricken, I send you the following extracts from one of the leading Moscow papers:—

"'Every possible sacrifice must be made to aid the distress, which is now at its height. The spring has now come, when the moujiks need all their energies for their work, and they seem to have lost all hope and energy. Instead of our rich and powerful "Mother Russia," there lies before us a bewitched country teeming with starving beggars. In travelling from village to village, and in passing from cottage to cottage, one wonders how human beings can remain human while living in such a terrible situation. To make matters worse, the general need does not grow less; it increases with terrible power. The aid now being given is altogether insufficient in proportion to the distress, and reminds one of a jet of water that is being directed on a house burning on all sides.'

"Letters of this kind are now filling the Press at the eleventh hour, when the actual state of things was known to thousands in Russia six months ago. A landowner, who at first made appeals for aid, and is himself now besieged for help, writes: 'Those who are living far away cannot believe that all this suffering is so terrible, and that now on the eve of a great national holiday, the centenary of Pushkine, which aims at glorifying Russian culture, the value of human life in Russia has sunk to a few roubles. Yet such is the state of the case. At the cost of a bottle of champagne it is possible to save several human lives. If we were even now to make up the total of the famine-stricken, we should arrive at figures before which no living soul could fail to be touched.' Some authorities put the number of starving moujiks at 20,000,000; others say the number is far less. Strange to say, the peasants bear their sufferings with a resignation worthy of martyrs. They regard the famine as being the will of God, or as a punishment for their sins. Were not this religious spirit of resignation the spirit of 'Kismet,' so strongly developed among the Russian peasantry, the interior of the country would now be the scene of rapine and revolt. The village priests tell their flocks that it is the will of God that they should thus starve, or that it is the will of the saints; thus the simple, uncomplaining moujik sinks into death without a murmur on his lips. Life, even at the best, is scarcely worth living for the majority of Russian peasants.

"The poor sufferers have hit on all kinds of devices in order to still the pangs of hunger. A friend of mine, who has just visited the peasants in the Government of Kazan, states that the women in one cottage were in the habit of heating the stove in the evening, and then of allowing the fumes to spread through the room instead of escaping properly by the chimney. As a result of this, all the inmates lost their senses until the morning, and thus the pangs of hunger were escaped until dawn. The experiment is highly dangerous; but the women plead that it is better thus to die in one's sleep than to perish slowly of hunger. These little devices, which the peasants relate with an attempt at grim humour, are only too common.

they are in all regions with continental climates north of the 45th parallel—and the ripening of wheat requires a temperature averaging at least 65° Fahr. for fifty-five to sixty-five days. As all Siberia lies north of the summer isotherm of 65°, it follows that such region is ill adapted to wheat culture unless some compensating climatic condition exists. As a fact, the conditions are exceptionally unfavourable in all but very limited districts in the two westernmost governments. The cultivable lands of Western Siberia adapted to grain-bearing neither equal in extent nor in potential productive powers those of Iowa, Minnesota, and Nebraska.

"'Last August,' a correspondent of one of the leading journals of Moscow writes, 'it was well known that in many districts the land did not hold out a single hope for the peasantry, and that hundreds of thousands of people must endure the so-called "half-famine"; that is, they would receive assistance every month which would enable them to live for two weeks without starving. The result of this state of affairs was not long in making itself felt; the population became exhausted, and began to die.'

"In the Government of Kazan alone, even in March, there were more than 10,000 people helplessly ill. But this number is, of course, much lower than the actual figures, because the doctors were not able to help the suffering. The 'circuits' allotted to the country doctors contain often as many as 50,000 persons to be attended by one doctor. The sickness was even greater in the Government of Samara during the last famine. It is, nevertheless, a fact that during the height of the distress, the existence of the last famine was stoutly denied by the *Novoe Vremya*, the *Grashdanin*, and by other leading journals in Russia.

"The peasants are so wretchedly poor for the greater part that they have not the means to pay for medical attendance; in consequence, most of the doctors congregate in the towns, and the country districts are thus left practically bare of medical aid. I have known districts containing from 20,000 to 30,000 inhabitants with only one doctor to minister to the wants of thousands of sick persons. Such is the state of the country; in the towns it is far different, for they contain some of the best doctors and the finest hospitals in the world. It is said that the hospitals of Moscow and St. Petersburg are second to none in Europe as regards order, cleanliness, and being up to date in every respect. In the interior of the Empire doctors and hospitals are few and far between. I may say, in conclusion, that the Russian moujik has so far reduced his wants that, as an actual fact, he is now able to exist during the present famine on three or four kopecks a day; in other words, a shilling will keep him alive for about a fortnight."

There are limited tracts of fair productiveness in Central Siberia, and in the valleys of the southern affluents of the Amoor, but these are only just capable of supporting a meagre population.

Prince Hilkoff, Russian Minister of Ways and Communications, declared in 1896 that "Siberia never had produced, and never would produce, wheat and rye enough to feed the Siberian population." And, a year later, Prince Kropotkin backed the statement as substantially correct.

Those who attended the meeting of the British Association last year in Canada must have been struck with the extent and marvellous capacity of the fertile plains of Manitoba and the North-West Provinces. Here were to be seen 1,290,000 acres of fine wheat-growing land yielding 18,261,950 bushels, one-fifth of which comes to hungry England. Expectations have been cherished that the Canadian North-West would easily supply the world with wheat, and exaggerated estimates are drawn as to the amount of surplus land on which wheat can be grown. Thus far performance has lagged behind promise, the wheat-bearing area of all Canada having increased less than 500,000 acres since 1884, while the exports have not increased in greater proportion. As the wheat area of Manitoba and the North-West has increased, the wheat area of Ontario and the Eastern Provinces has decreased, the added acres being little more than sufficient to meet the growing requirements of population. We have seen calculations showing that Canada contains 500,000,000 acres of profitable wheat land. The

impossibility of such an estimate ever being fulfilled will be apparent when it is remembered that the whole area employed in both temperate zones for growing all the staple food crops is not more than 580,000,000 acres, and that in no country has more than 9 per cent. of the area been devoted to wheat culture.

The most trustworthy estimates give Canada a wheat area of not more than 6,000,000 acres in the next twelve years, increasing to a maximum of 12,000,000 acres in twenty-five years. The development of this promising area necessarily must be slow, since prairie land cannot be laid under wheat in advance of a population sufficient to supply the needful labour at seed time and harvest. As population increases so do home demands for wheat.

The net exports average 8,970,000 bushels yearly, being 24·3 per cent. of the net product.[1]

The fertility of the North-West Provinces of the Dominion is due to an exceptional and curious circumstance. In winter the ground freezes to a

[1] TABLE X.

Acreage, Crop, and Exports of Wheat from Canada from 1891 *to* 1896 :—

Year	Population	Acres	Total bushels	Bushels exported
1891	4,833,000	2,690,000	62,600,000	3,000,000
1892	4,885,000	2,910,000	49,700,000	10,200,000
1893	4,936,000	2,800,000	42,700,000	11,000,000
1894	4,986,000	2,550,000	44,600,000	11,000,000
1895	5,040,000	2,560,000	57,500,000	9,200,000
1896	5,090,000	2,700,000	40,800,000	10,400,000
1897	5,140,000	2,900,000	56,600,000	8,000,000

considerable depth. Wheat is sown in the spring, generally April, when the frozen ground has been thawed to a depth of 3 inches. Under the hot sun of the short summer the grain sprouts with surprising rapidity, partly because the roots are supplied with water from the thawing depths. The summer is too short to thaw the ground thoroughly, and gate-posts or other dead wood extracted in autumn are found still frozen at their lower ends.

Australasia, as a potential contributor to the world's supply of wheat, affords another fertile field for speculation. Climatic conditions limit the Australian wheat area to a small portion of the southern littoral belt. Professor Shelton considers there are still 50,000,000 acres in Queensland suitable for wheat, but hitherto it has never had more than 150,000 acres under cultivation. Crops in former days were liable to rust, but since the Rust in Wheat Conferences, and the dissemination of instructions to farmers, rust no longer has any terrors. I am informed by the Queensland Department of Agriculture that of late years they practically have raised wheat vigorous enough to resist this plague. For the second season in succession the wheat crop last year was destroyed over large areas in Victoria; and in South Australia the harvest averaged not more than about $3\frac{3}{4}$ bushels per acre after meeting Colonial requirements for food and seed, leaving only 684,000 bushels for export. In most other districts the yield falls to such an extent as to cause Europeans to wonder why the pursuit of wheat-raising is continued.

New Zealand has a moist climate resembling that of Central and Southern England, while South Australia is semi-arid, resembling Western Kansas. Only two countries in the world yield as much wheat per acre as New Zealand—these are Denmark and the United Kingdom. Notwithstanding the great yield of wheat, due to an equable climate, New Zealand finds fruit and dairy farming still more profitable. The climatic conditions favourable to wheat are also conducive to luxuriant growths of nutritious grasses. Thus the New Zealander ships his butter more than halfway round the world, and competes successfully with Western Europe.

During the last twenty-seven years the Austro-Hungarian population has increased 21·8 per cent. as against an increase of 54·6 per cent. in the acreage of wheat. Notwithstanding this disparity in the rates of increase, exports have practically ceased by reason of an advance of nearly 80 per cent. in unit consumption. There can be little doubt that Austria-Hungary is about to enter the ranks of importing nations, although in Hungary a considerable area of wheat land remains to be brought under cultivation.

The land under wheat in Austria-Hungary, according to the latest official figures, is 11,000,000 acres. The 1897–98 crop, including that of Croatia-Slavonia, is 55,000,000 bushels below that of 1896–97, and as exports during the last five years have averaged less than 4,000,000 bushels per annum, the imports of wheat are expected to be large.

Roumania is an important wheat-growing country.

In 1896 it produced 69,000,000 bushels, and exported 34,000,000 bushels. It has a considerable amount of surplus land which can be used for wheat, although for many years the wheat area is not likely to exceed home requirements.

France comes next to the United States as a producer of wheat; but for our purpose she counts but little, being dependent on supplies from abroad for an average quantity of 14 per cent. of her own production. There is practically no spare land in France that can be put under wheat in sufficient quantity to enable her to do more than provide for increase of population.

Germany is a gigantic importer of wheat, her imports rising 700 per cent. in the last twenty-five years, and now averaging 35,000,000 bushels. Other nations of Europe, also importers, do not require detailed mention, as under no conceivable conditions would they be able to do more than supply wheat for the increasing requirements of their local population, and, instead of replenishing, would probably diminish the world's stores.

The prospective supply of wheat from Argentina and Uruguay has been greatly overrated. The agricultural area includes less than 100,000,000 acres of good, bad, and indifferent land, much of which is best adapted for pastoral purposes. There is no prospect of Argentina ever being able to devote more than 30,000,000 acres to wheat; the present wheat area is about 6,000,000 acres, an area that may be doubled in the next twelve years. But the whole arable region is subject to great climatic vicissitudes,

and to frosts that ravage the fields south of the 37th parallel. Years of systematised energy are frustrated in a few days—perhaps hours—by a single cruelty of Nature, such as a plague of locusts, a tropical rain, or a devastating hail storm. It will take years to bring the surplus lands of Argentina into cultivation, and the population is even now insufficient to supply labour at seed time and harvest.

During the next twelve years, Uruguay may add 1,000,000 acres to the world's wheat fields; but social, political, and economic conditions seriously interfere with agricultural development.

At the present time South Africa is an importer of wheat, and the regions suitable to cereals do not exceed a few million acres. Great expectations have been formed as to the fertility of Mashonaland, the Shiré Highlands, and the Kikuyu plateau, and as to the adaptation of these regions to the growth of wheat. But wheat culture fails where the banana ripens, and the banana flourishes throughout Central Africa, except in limited areas of great elevation. In many parts of Africa insect pests render it impossible to store grain, and without grain-stores there can be little hope of large exports.

North Africa, formerly the granary of Rome, now exports less than 5,000,000 bushels of wheat annually, and these exports are on the decline, owing to increased home demands. With scientific irrigation, Egypt could supply three times her present amount of wheat, although no increase is likely unless the cotton fields of the Delta are diverted to grain growing. In Algeria and Tunis nearly all reclaimed lands

are devoted to the production of wine, for which a brisk demand exists. Were this land devoted to the growth of wheat, an additional 5,000,000 bushels might be obtained.

The enormous acreage devoted to wheat in India has been declining for some years, and in 1895 over 20,000,000 acres yielded 185,000,000 bushels. Seven-eighths of this harvest is required for native consumption, and only one-eighth on an average is available for export. The annual increase of population is more than 3,000,000, demanding an addition to the food-bearing lands of not less than 1,800,000 acres annually. In recent years the increase has been less than one-fourth of this amount.[1]

In surveying the limitations and vicissitudes of wheat crops, I have endeavoured to keep free from exaggeration, and have avoided insistence on doubtful points. I have done my best to get trustworthy facts and figures, but from the nature of the case it is impossible to attain complete accuracy. Great caution is required in sifting the numerous varying current statements respecting the estimated areas and total produce of wheat throughout the world. The more closely official estimates are examined,

[1] So long ago as 16th April, 1891, the following statement, by a leading Indian economist, appeared in the *Daily Englishman* of Calcutta: "People do not realise the fact that all the wheat India produces is required for home consumption, and that this fact is not likely to be realised until a serious disaster occurs, and that even now less than 9 per cent. is exported. It is a self-evident fact that a slight expansion of consumption, or a partial failure of crops of other food grains, will be sufficient to absorb the small proportion now exported. Besides, we have a steady increase of consumption, in consequence of the natural growth of the population, as well as in the gradual improvement of the condition of a considerable part of the people in the cities. I believe that, comparatively speaking, India will in a few years cease to export wheat, and soon thereafter become an importing country."

the more defective are they found, and comparatively few figures are sufficiently well established to bear the deductions often drawn. In doubtful cases I have applied to the highest authorities in each country, and in the case of conflicting accounts have taken data the least favourable to sensational or panic-engendering statements. In a few instances of accurate statistics their value is impaired by age; but for 95 per cent. of my figures I quote good authorities, while for the remaining 5 per cent. I rely on the best commercial estimates derived from the appearance of the growing crops, the acreage under cultivation, and the yield last year. The maximum probable error would make no appreciable difference in my argument.

The facts and figures I have set before you are easily interpreted. Since 1871 unit consumption of wheat, including seed, has slowly increased in the United Kingdom to the present amount of 6 bushels per head per annum; while the rate of consumption for seed and food by the whole world of bread-eaters was 4·15 bushels per unit per annum for the eight years ending 1878, and at the present time is 4·5 bushels. Under present conditions of low-acre yield, wheat cannot long retain its dominant position among the food stuffs of the civilised world. The details of the impending catastrophe no one can predict, but its general direction is obvious enough. Should all the wheat-growing countries add to their area to the utmost capacity, on the most careful calculation the yield would give us only an addition of some 100,000,000 acres, supplying at

the average world-yield of 12·7 bushels to the acre, 1,270,000,000 bushels, just enough to supply the increase of population among bread-eaters till the year 1931.[1]

At the present time there exists a deficit in the wheat area of 31,000 square miles—a deficit masked by the fact that the ten world crops of wheat harvested in the ten years ending 1896 were more than 5 per cent. above the average of the previous twenty-six years.

When provision shall have been made, if possible, to feed 230,000,000 units likely to be added to the bread-eating populations by 1931—by the complete occupancy of the arable areas of the temperate zone now partially occupied—where can be grown the additional 330,000,000 bushels of wheat required ten years later by a hungry world? What is to happen if the present rate of population be maintained, and if arable areas of sufficient extent cannot be adapted and made contributory to the subsistence of so great a host?

Are we to go hungry, and to know the trial of scarcity? That is the poignant question. Thirty years is but a day in the life of a nation. Those present who may attend the meeting of the British Association thirty years hence will judge how far my forecasts are justified.

If bread fails—not only us, but all the bread-

[1] An average wheat crop on the 1897–98 acreage would be 2,070,000,000 bushels. Adding to this 1,270,000,000 bushels makes a grand total of 3,340,000,000 bushels. But the estimate on page 11 shows that in the year 1931 the bread-eaters will require 3,357,000,000 bushels. Thus there will be in 1931 a deficiency of 17,000,000 bushels, unless the average yield per acre be increased.

eaters of the world—what are we to do? We are born wheat-eaters. Other races, vastly superior to us in numbers, but differing widely in material and intellectual progress, are eaters of Indian corn, rice, millet, and other grains; but none of these grains have the food value, the concentrated, health-sustaining power of wheat, and it is on this account that the accumulated experience of civilised mankind has set wheat apart as the fit and proper food for the development of muscle and brains.

It is said that when other wheat-exporting countries realise that the States can no longer keep pace with the demand, these countries will extend their area of cultivation, and struggle to keep up the supply *pari passu* with the falling off in other quarters. But will this comfortable and cherished doctrine bear the test of examination?

Cheap production of wheat depends on a variety of causes, varying greatly in different countries. Taking the cost of producing a given quantity of wheat in the United Kingdom at 100s., the cost for the same amount in the United States is 67s., in India 66s., and in Russia 54s. We require cheap labour, fertile soil, easy transportation to market, low taxation and rent, and no export or import duties. Labour will rise in price, and fertility diminish as the requisite manurial constituents in the virgin soil become exhausted. Facility of transportation to market will be aided by railways, but these are slow and costly to construct, and it will not pay to carry wheat by rail beyond a certain distance. These considerations show that the price of wheat tends

to increase. On the other hand, the artificial impediments of taxation and customs duties tend to diminish as demand increases and prices rise.

I have said that starvation may be averted through the laboratory. Before we are in the grip of actual dearth the chemist will step in and postpone the day of famine to so distant a period that we, and our sons and grandsons, may legitimately live without undue solicitude for the future.

It is now recognised that all crops require what is called a "dominant" manure. Some need nitrogen, some potash, others phosphates. Wheat pre-eminently demands nitrogen, fixed in the form of ammonia or nitric acid. All other necessary constituents exist in the soil; but nitrogen is mainly of atmospheric origin, and is rendered "fixed" by a slow and precarious process which requires a combination of rare meteorological and geographical conditions to enable it to advance at a sufficiently rapid rate to become of commercial importance.

There are several sources of available nitrogen. The distillation of coal in the process of gas-making yields a certain amount of its nitrogen in the form of ammonia; and this product, as sulphate of ammonia, is a substance of considerable commercial value to gas companies. But the quantity produced is comparatively small; all Europe does not yield more than 400,000 annual tons, and, in view of the unlimited nitrogen required to substantially increase the world's wheat crop, this slight amount of coal ammonia is not of much significance. For a long time guano has been one of the most important

sources of nitrogenous manures, but guano deposits are so near exhaustion that they may be dismissed from consideration.

Much has been said of late years, and many hopes raised by the discovery of Hellriegel and Wilfarth, that leguminous plants bear on their roots nodosities abounding in bacteria endowed with the property of fixing atmospheric nitrogen; and it is proposed that the necessary amount of nitrogen demanded by grain crops should be supplied to the soil by cropping it with clover and ploughing in the plant when its nitrogen assimilation is complete. But it is questionable whether such a mode of procedure will lead to the lucrative stimulation of crops. It must be admitted that practice has long been ahead of science, and for ages farmers have valued and cultivated leguminous crops. The four-course rotation is turnips, barley, clover, wheat—a sequence popular more than two thousand years ago. On the Continent, in certain localities, there has been some extension of microbe cultivation; at home we have not reached even the experimental stage. Our present knowledge leads to the conclusion that the much more frequent growth of clover on the same land, even with successful microbe-seeding and proper mineral supplies, would be attended with uncertainty and difficulties. The land soon becomes what is called "clover sick," and turns barren.

There is still another and invaluable source of fixed nitrogen. I mean the treasure locked up in the sewage and drainage of our towns. Individually

the amount so lost is trifling, but multiply the loss by the number of inhabitants, and we have the startling fact that, in the United Kingdom, we are content to hurry down our drains and water-courses, into the sea, fixed nitrogen to the value of no less than £16,000,000 per annum. This unspeakable waste continues, and no effective and universal method is yet contrived of converting sewage into corn. Of this barbaric waste of manurial constituents Liebig, nearly half a century ago, wrote in these prophetic words: "Nothing will more certainly consummate the ruin of England than a scarcity of fertilisers—it means a scarcity of food. It is impossible that such a sinful violation of the divine laws of Nature should for ever remain unpunished; and the time will probably come for England sooner than for any other country, when, with all her wealth in gold, iron, and coal, she will be unable to buy one-thousandth part of the food which she has, during hundreds of years, thrown recklessly away."

The more widely this wasteful system is extended, recklessly returning to the sea what we have taken from the land, the more surely and quickly will the finite stocks of nitrogen locked up in the soils of the world become exhausted. Let us remember that the plant creates nothing; there is nothing in bread which is not absorbed from the soil, and unless the abstracted nitrogen is returned to the soil, its fertility must ultimately be exhausted. When we apply to the land nitrate of soda, sulphate of ammonia, or guano, we are drawing on the earth's capital, and our drafts will not perpetually be

honoured. Already we see that a virgin soil cropped for several years loses its productive powers, and without artificial aid becomes infertile. Thus the strain to meet demands is increasingly great. Witness the yield of 40 bushels of wheat per acre under favourable conditions, dwindling through exhaustion of soil to less than 7 bushels of poor grain, and the urgency of husbanding the limited store of fixed nitrogen becomes apparent. The store of nitrogen in the atmosphere is practically unlimited, but it is fixed and rendered assimilable by plants only by cosmic processes of extreme slowness. The nitrogen which with a light heart we liberate in a battleship broadside has taken millions of minute organisms patiently working for centuries to win from the atmosphere.[1]

The only available compound containing sufficient fixed nitrogen to be used on a world-wide scale as a nitrogenous manure is nitrate of soda, or Chili saltpetre. This substance occurs native over a narrow band of the plain of Tamarugal, in the northern provinces of Chili between the Andes and the coast hills. In this rainless district, for countless ages, the continuous fixation of atmospheric nitrogen by the soil, its conversion into nitrate by the slow transformation of billions of nitrifying organisms, its combination with soda, and the

[1] Sir Andrew Noble informs me that a first-class battleship would carry about 63 tons of cordite, and we may suppose that in a general action 40 tons of this would be expended. Now, at Trafalgar, Nelson had twenty-seven line-of-battle ships, and the allied forces thirty-three. If we suppose a similar number of modern battleships and first-class cruisers to be engaged, and each to expend 40 tons of cordite, the total volume of nitrogen set free would be 302,400 cubic metres, or about 380 tons, equivalent to 2,300 tons of nitrate of soda.

crystallisation of the nitrate have been steadily proceeding, until the nitrate fields of Chili have become of vast commercial importance, and promise to be of inestimably greater value in the future. The growing exports of nitrate from Chili at present amount to about 1,200,000 tons.

At the present time the contributory areas[1] devoted to the world's growth of wheat are about 163,000,000 acres. These do not include some 40,000,000 acres in India, Persia, Turkey in Asia, and North Africa. At the average of 12·7 bushels per acre this gives 2,070,000,000 bushels. But thirty years hence the demand will be 3,260,000,000 bushels, and there will be difficulty in finding the necessary acreage on which to grow the additional amount required. By increasing the present yield per acre from 12·7 to 20 bushels we should, with our present acreage, secure a crop of the requisite amount. Now, from 12·7 to 20 bushels per acre is a moderate increase of productiveness, and there is no doubt that a dressing with nitrate of soda will give this increase and more.

The action of nitrate of soda in improving the yield of wheat has been studied practically by Sir John Lawes and Sir Henry Gilbert on their experimental field at Rothamsted. This field was sown with wheat for thirteen consecutive years without manure, and yielded an average of 11·9 bushels to the acre. For the next thirteen years it was sown with wheat, and dressed with 5 cwt. of nitrate of soda per acre, other mineral constituents also being

[1] *See* Note, p. 8.

present. The average yield for these years was 36·4 bushels per acre—an increase of 24·5 bushels. In other words, 22·86 lb. of nitrate of soda produce an increase of one bushel of wheat.

At this rate, to increase the world's crop of wheat by 7·3 bushels, about 1½ cwt. of nitrate of soda must annually be applied to each acre. The amount required to raise the world's crop on 163,000,000 acres from the present supply of 2,070,000,000 bushels to the required 3,260,000,000 bushels will be 12,000,000 tons, distributed in varying amounts over the wheat-growing countries of the world. The countries which produce more than the average of 12·7 bushels will require less, and those below the average will require more; but, broadly speaking, about 12,000,000 tons annually of nitrate of soda will be required, in addition to the 1,250,000 tons already absorbed by the world.

It is difficult to get trustworthy estimates of the amount of nitrate surviving in the nitre beds. Common rumour declares the supply to be inexhaustible, but cautious local authorities state that at the present rate of export, of over 1,000,000 tons per annum, the raw material "caliche," containing from 25 to 50 per cent. nitrate, will be exhausted in from twenty to thirty years.

Dr. Newton, who has spent years on the nitrate fields, tells me there is a lower-class material, containing a small proportion of nitrate, which cannot at present be used, but which may ultimately be manufactured at a profit. Apart from a few of the more scientific manufacturers, no one is sanguine

enough to think this debatable material will ever be worth working. If we assume a liberal estimate for nitrate obtained from the lower grade deposit, and say that it will equal in quantity that from the richer quality, the supply may last, possibly, fifty years, at the rate of 1,000,000 tons a year; but, at the rate required to augment the world's supply of wheat to the point demanded thirty years hence, it will not last more than four years.

I have passed in review all the wheat-growing countries of the world, with the exception of those whose united supplies are so small as to make little appreciable difference to the argument. The situation may be summed up briefly thus: The world's demand for wheat—the leading breadstuff—increases in a crescendo ratio year by year. Gradually all the wheat-bearing land on the globe is appropriated to wheat-growing, until we are within measurable distance of using the last available acre. We must then rely on nitrogenous manures to increase the fertility of the land under wheat, so as to raise the yield from the world's low average—12·7 bushels per acre—to a higher average. To do this efficiently, and feed the bread-eaters for a few years, will exhaust all the available store of nitrate of soda. For years past we have been spending fixed nitrogen at a culpably extravagant rate, heedless of the fact that it is fixed with extreme slowness and difficulty, while its liberation in the free state takes place always with rapidity, and sometimes with explosive violence.

Some years ago Mr. Stanley Jevons uttered a

note of warning as to the near exhaustion of our British coal-fields. But the exhaustion of the world's stock of fixed nitrogen is a matter of far greater importance. It means not only a catastrophe little short of starvation for the wheat-eaters, but, indirectly, scarcity for those who exist on inferior grains, together with a lower standard of living for meat-eaters, scarcity of mutton and beef, and even the extinction of gunpowder.

There is a gleam of light amid this darkness of despondency. In its free state nitrogen is one of the most abundant and pervading bodies on the face of the earth. Every square yard of the earth's surface has nitrogen gas pressing down on it to the extent of about 7 tons; but this is in the *free* state, and wheat demands it *fixed*. To convey this idea in an object-lesson, I may tell you that, previous to its destruction by fire, Colston Hall, measuring 146 feet by 80 feet by 70 feet, contained 27 tons weight of nitrogen in its atmosphere; it also contained one-third of a ton of argon. In the free gaseous state this nitrogen is worthless; combined in the form of nitrate of soda it would be worth about £2,000.

For years past attempts have been made to effect the fixation of atmospheric nitrogen, and some of the processes have met with sufficient partial success to warrant experimentalists in pushing their trials still further; but I think I am right in saying that no process has yet been brought to the notice of scientific or commercial men which can be considered successful either as regards cost or yield

of product. It is possible, by several methods, to fix a certain amount of atmospheric nitrogen; but to the best of my knowledge no process has hitherto converted more than a small amount, and this at a cost largely in excess of the present market value of fixed nitrogen.

The fixation of atmospheric nitrogen therefore is one of the great discoveries awaiting the ingenuity of chemists. It is certainly deeply important in its practical bearings on the future welfare and happiness of the civilised races of mankind. This unfulfilled problem, which so far has eluded the strenuous attempts of those who have tried to wrest the secret from nature, differs materially from other chemical discoveries, which are in the air so to speak, but are not yet matured. The fixation of nitrogen is vital to the progress of civilised humanity. Other discoveries minister to our increased intellectual comfort, luxury, or convenience; they serve to make life easier, to hasten the acquisition of wealth, or to save time, health, or worry. The fixation of nitrogen is a question of the not far-distant future. Unless we can class it among certainties to come, the great Caucasian race will cease to be foremost in the world, and will be squeezed out of existence by races to whom wheaten bread is not the staff of life.

Let me see if it is not possible even now to solve the momentous problem. As far back as 1892 I exhibited, at one of the soirées of the Royal Society, an experiment on "The Flame of Burning Nitrogen." I showed that nitrogen is a combustible gas, and the reason why when once ignited the flame does not

spread through the atmosphere and deluge the world in a sea of nitric acid is, that its igniting point is higher than the temperature of its flame—and not, therefore, hot enough to set fire to the adjacent mixture. But by passing a strong electric current between terminals the air takes fire, and continues to burn with a powerful flame, producing nitrous and nitric acids. This inconsiderable experiment may not unlikely lead to the development of a mighty industry destined to solve the great food problem. With the object of burning out nitrogen from air so as to leave argon behind, Lord Rayleigh fitted up apparatus for performing the operation on a larger scale, and succeeded in effecting the union of 29·4 grammes of mixed nitrogen and oxygen at an expenditure of one horse-power. Following these figures it would require one Board of Trade unit to form 74 grammes of nitrate of soda, and therefore 14,000 units to form one ton. To generate electricity in the ordinary way with steam engines and dynamos, it is now possible, with a steady load night and day, and engines working at maximum efficiency, to produce current at a cost of one-third of a penny per Board of Trade unit. At this rate one ton of nitrate of soda would cost £26. But electricity from coal and steam engines is too costly for large industrial purposes; at Niagara, where water power is used, electricity can be sold at a profit for one-seventeenth of a penny per Board of Trade unit. At this rate nitrate of soda would cost not more than £5 per ton. But the limit of cost is not yet reached, and it must be remembered that the initial data are derived

from small scale experiments, in which the object was not economy, but rather to demonstrate the practicability of the combustion method, and to utilise it for isolating argon. Even now electric nitrate at £5 a ton compares favourably with Chili nitrate at £7 10s. a ton; and all experience shows that when the road has been pointed out by a small laboratory experiment, the industrial operations that may follow are always conducted at a cost considerably lower than could be anticipated from the laboratory figures.

Before we decide that electric nitrate is a commercial possibility, a final question must be mooted. We are dealing with wholesale figures, and must take care that we are not simply shifting difficulties a little further back without really diminishing them. We start with a shortage of wheat, and the natural remedy is to put more land under cultivation. As the land cannot be stretched, and there is so much of it and no more, the object is to render the available area more productive by a dressing with nitrate of soda. But nitrate of soda is limited in quantity, and will soon be exhausted. Human ingenuity can contend even with these apparently hopeless difficulties. Nitrate can be produced artificially by the combustion of the atmosphere. Here we come to finality in one direction; our stores are inexhaustible. But how about electricity? Can we generate enough energy to produce 12,000,000 tons of nitrate of soda annually? A preliminary calculation shows that there need be no fear on that score; Niagara alone is capable of supplying the required

electric energy without much lessening its mighty flow.

The future can take care of itself. The artificial production of nitrate is clearly within view, and by its aid the land devoted to wheat can be brought up to the 30 bushels per acre standard. In days to come, when the demand may again overtake supply, we may safely leave our successors to grapple with the stupendous food problem.

And, in the next generation, instead of trusting mainly to foodstuffs which flourish in temperate climates, we probably shall trust more and more to the exuberant foodstuffs of the tropics, where, instead of one yearly sober harvest, jeopardised by any shrinkage of the scanty days of summer weather, or of the few steady inches of rainfall, Nature annually supplies heat and water enough to ripen two or three successive crops of foodstuffs in extraordinary abundance. To mention one plant alone, Humboldt—from what precise statistics I know not—computed that, acre for acre, the food-productiveness of the banana is 133 times that of wheat—the unripe banana, before its starch is converted into sugar, is said to make excellent bread.

Considerations like these must in the end determine the range and avenues of commerce, perhaps the fate of continents. We must develop and guide Nature's latent energies, we must utilise her inmost workshops, we must call into commercial existence Central Africa and Brazil to redress the balance of Odessa and Chicago.

RECENT DEVELOPMENTS OF THE WHEAT PROBLEM

EIGHTEEN years have elapsed since the preceding address was delivered before the British Association for the Advancement of Science at Bristol, and was greeted with much adverse criticism.

Time has shown that some of my estimates were on the whole correct, while in other cases my views have not been entirely borne out, and my critics have been proved to be justified. For example, it was affirmed in a widely circulated pamphlet by Mr. Edward Atkinson, of Boston, U.S.A., that the United States of America could supply the whole world's demand for wheat, and that the Republic would be ready to contract for the supply of the United Kingdom for the next thirty years provided we would offer a dollar a bushel in Mark Lane as a permanent price. When, however, the United States harvests for the decades 1881–90, 1891–1900, and 1901–10 are compared with the total world's harvests for the same periods, it is found that they amount to only 19 per cent., 22 per cent., and 20 per cent. of the totals respectively, which does not appear to indicate that the United States is capable of becoming the world's wheat provider. The decrease in the percentage contributed in the third as compared with the second period may be ascribed to the fact that not only did settlement cease to extend westward over prairies lying east of the Rocky Mountains, but,

despite a vast increase in the number of would-be farmers, the entire western border of the prairie region began to lose population, with a consequent abandonment of cultivation, in whole or in part, over immense areas. When several millions of acres were first added to the lands of Oklahoma there were ten applicants for every 160-acre tract available. Among these land seekers were numbers who had crossed the continent westward in search of a home upon the public domain; but these nomads, not finding a desirable location on the Pacific Slope, had returned nearly 2,000 miles to seek an abiding place in Oklahoma. From the Canadian boundary, through the Dakotas, Nebraska, Eastern Colorado, Kansas and Texas, the settlers in the early 'eighties marched up the great continental Slope, in many cases beguiled by false representations as to the character of the climate and soil. After exhausting their slender means, suffering repeated crop failures and desperate privations, these settlers were actually starved out and compelled to return down the Slope.

The tide began to ebb in 1887 and was at full flood from 1888 to 1894. The biennial reports of the Kansas State Board of Agriculture and other official publications show that thirty-seven counties in the western third of that State lost 45 per cent. of population (an exclusively agricultural one) between 1888 and 1898. So great was the dispersion that some of the counties barely retained sufficient people to conduct municipal and judicial affairs. Farms and homes on the arid prairies were

abandoned, not because of the unwillingness of the people to grow wheat at current prices, but because wheat refused to grow one year in three. The settlers exhausted their own means, and often that of friends, and mortgaged their lands for the means of subsistence. Crops again failing, the unfortunates were glad to accept loans of seed wheat from the State and from railway companies, who made such loans to retain population and traffic. Despite these efforts railways were abandoned, and the rails themselves removed from numbers of the luckless districts. Russian emigrants, however, employing Russian methods and varieties of seed, proved more successful in wheat-growing in these drier regions, and it is now known that the crop may be profitably raised if a species such as the cluvum is used, which requires little moisture and has other valuable qualities. It is said that a wheat crop may be grown and harvested without receiving any rain whatever if surface mulching is efficiently performed and suitable rotations are introduced. Another statement by the same critic was to the effect that there were then in the United States fully 100,000 square miles of land, 64 million acres, fully suitable to the production of wheat at 15 bushels to the acre, practically unoccupied in any branch of agriculture, which would be devoted to wheat on an assured price of a dollar a bushel (33 shillings a quarter) in Mark Lane, yielding 960 million bushels. The acreage under wheat and the yield per acre have steadily crept up, and it has been estimated recently that as much as 1,000 million bushels may possibly

be obtained from the United States, and an equal amount from Canada, where Saskatchewan has seen an extraordinary increase in wheat-growing in the last few years. But 1,000 million bushels is less than one-third of the world's harvest, which has increased 43 per cent. in three decades.

I propose in this appendix to discuss shortly some of the new data which have been accumulated and to consider the wheat problem in the light of our growing knowledge of its nature, and of our realisation of the importance of the question of our food supply. The time has come to take stock of the resources and needs of the civilised world, and in particular of the possibility of, and urgent necessity for, increasing our home wheat supply. The first step towards the betterment of our position is the consideration of the scientific, practical, and economical aspects of the question of the cultivation of the wheat crop. In this connection the statistics which have recently been given of the comparative produce per hundred acres of cultivated land in Great Britain and Germany provide food for serious thought. These are given in the following striking table, which is based upon data recently published in the Yellow Book of the Board of Agriculture (Cd. 8305).

TABLE XI.

Average Farm Produce of 100 *Acres of Cultivated Land.*

GREAT BRITAIN.	GERMANY.
15 tons corn	33 tons corn
11 tons potatoes	55 tons potatoes
4 tons meat	4½ tons meat
170 tons milk	28 tons milk
Negligible quantity of sugar	2¾ tons sugar

The British farmer feeds from 45 to 50 persons per 100 acres, while the German farmer feeds from 70 to 75.

The comparative value of the produce per acre of British and Belgian land, which closely resembles it as far as natural fertility is concerned, is said to be as 19 : 80, so that the British farmer appears to be very much behind the Continental farmer in extracting money from the soil. The explanation of the greater productivity of the German farm becomes clearly apparent when the consumption of artificial fertilisers is examined. This is shown in the following table.

TABLE XII.

Average Consumption of Fertilisers per Acre.

	Potash Fertilisers.	Nitrogenous Fertilisers.
Germany. . .	10·68 lb.	7·21 lb.
France . . .	0·71 ,,	3·65 ,,
United Kingdom .	0·09 ,,	2·22 ,,

It is said that Germany imports about ten times as much Chilian nitrate as the United Kingdom, and one-third of all the nitrate exported is consumed by Germany alone; hence it is hardly surprising that the yield per acre of German farms has nearly doubled in thirty years.

The unit consumption of wheat in the United Kingdom has not appreciably increased since 1898. In the decade 1891–1900 the consumption per head of population was 5·9 bushels, while in 1901–10 it had risen to 6·0 bushels. The percentage of supplies imported was 76 in the former and 80 in the latter

period. It is worth noticing that the corresponding figures for France and Germany are as follows :—

TABLE XIII.

	Consumption per head in bushels.		Percentage of supplies imported.	
	1891–1900.	1901–10.	1891–1900.	1901–10.
France . .	8·1	7·8	11	3
Germany .	2·9	3·1	27	36

These data have been obtained from a valuable paper on the " Statistical Study of Wheat Cultivation and Trade, 1881–1910," by Dr. T. F. Anstead, appearing in the *Geographical Journal* for August and September, 1913.

It is noteworthy that of the whole world production of wheat only 11 per cent. is exported, and of this amount the United Kingdom imports over 35 per cent. We grow only 20 per cent. of our total consumption. The average yield per acre in the United Kingdom rose to 28 bushels in 1901–10, while during the same period in the German Empire the rise was from 19 to 29 bushels per acre. The average yield over the whole world amounts to only 13 bushels per acre, the regions giving the lowest yields being parts of South America, Africa, Australia, and Russia in Europe. When the percentages exported are carefully examined, it is found that if the production of Germany, Russia, Austria, France, and Serbia were reduced by 10 per cent., and that of Belgium by 50 per cent., more than half the exportable surplus would disappear, and Russia, for example, would become an importer.

It was pointed out in the address that the area

in the United Kingdom under corn crops in 1897 was roughly 8·35 million acres, of which 1·94 million acres were given to wheat, and, moreover, it was shown that in order that we might be more independent of imports for our bread supply the total area devoted to corn crops would have to be used for bread alone. According to recent estimates, out of 47 million acres in Great Britain 8·5 millions, would be required to grow all our breadstuffs, which bears out the original statistics. In 1866 the wheat area was 3·7 million acres, which in 1913 had fallen to 1·8.

The Report of the Royal Commission on the Supply of Food and Raw Material in War Time which appeared in 1905 dealt with the question of our wheat supply, and laid stress upon the shortage of freight which would undoubtedly follow on the outbreak of hostilities. It was the opinion of the majority of the Commission that supplies would reach us in practically undiminished quantities, but naturally no allowance was made for the reduction of the world's supply owing to the deficiencies of the crops in the fighting area: the shortage of male labour in the belligerent countries, the diminution in the number of horses, and the difficulty of getting agricultural implements and supplies of manures must inevitably be contributory causes to this decrease, which may wipe out half the exportable surplus of wheat of the whole world. But without taking into consideration this probable deficiency the Report pointed out that the requirements of the Admiralty must give rise to a shortage

of freight, and as we now know, the devastations of submarines have also seriously impaired our carrying power. Various suggestions were made to remedy the threatened failure of our wheat supply. For example, it was thought that our stocks of wheat might be very considerably increased by providing warehouses for grain at our principal ports; a Government subsidy amounting to 6d. per quarter per annum was to be given to these warehouses, which would in return provide free storage for wheat. A scheme of Government insurance was also suggested against losses due to war. But the difficulties of storing grain in large quantities and at the same time preventing it from undergoing deterioration are very considerable, and, moreover, the purchase of it would necessarily force prices up. Again, a suggestion has been made that all the surplus wheat grown in the Empire should be brought to the United Kingdom instead of to any other importing country, but this would undoubtedly place the Dominions in an unfavourable position with regard to trade connections with other countries, and, moreover, it must be remembered that the harvests in Canada, Australia, and India, upon which we should be dependent, are very variable.

The only remedy against which no objections can be urged, although the difficulties of applying it are great, is to grow more of our own wheat. When the decline of wheat-growing in England is more investigated some rather remarkable facts are brought to light. For example, in 1801 there were 35½ acres of wheat per 100 of population in England and

Wales, while in 1914 the acreage per 100 people was reduced to 5. The quantities grown per head of population had decreased from 8½ to 1½ bushels in the same time. The following table, based upon the statistics of the Board of Agriculture, gives the areas under various crops, showing the relations between the ten years average and the year 1915.

TABLE XIV.

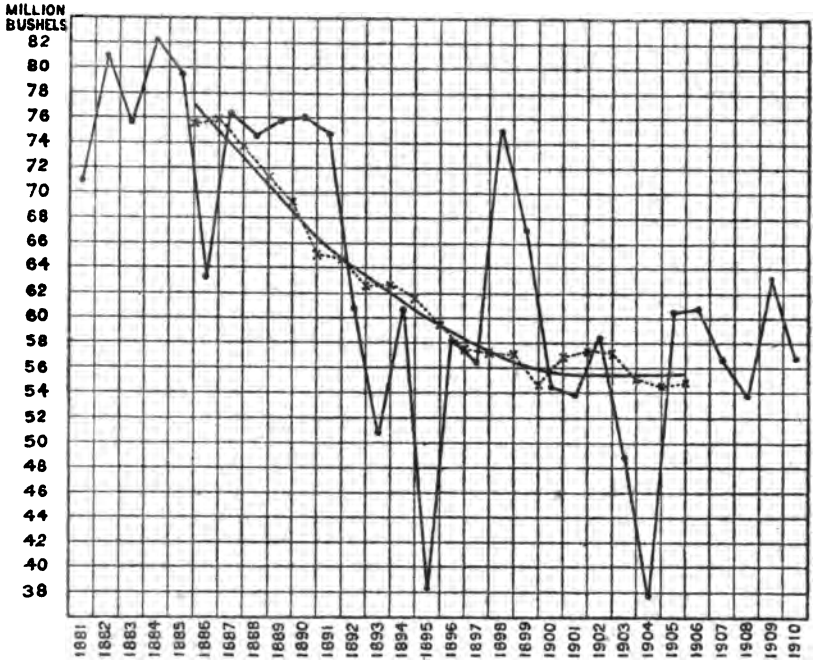
	Average of ten years. 1905–1914.	1915.	Differences.	
			Actual.	Per cent.
	Acres.	Acres.	Acres.	
All crops and grass .	27,280,740	27,053,100	−227,640	0·83
Arable land . .	11,356,799	10,965,707	−391,092	3·44
Permanent grass .	15,923,941	16,087,393	+163,452	1·03
Wheat . . .	11,735,927	2,170,170	+434,243	25·02
Potatoes . .	434,949	463,399	+ 28,450	6·54
Small fruit . .	76,291	74,187	− 2,104	2·76

The actual crops produced in 1915 and 1913 are compared in the following table, which shows the increase or decrease of each.

TABLE XV.

Crops.	1915.	1913.	Increase or decrease.
	Tons.	Tons.	Tons.
Wheat . . .	2,048,000	1,576,000	+ 472,000
Barley . . .	1,112,000	1,580,000	− 468,000
Oats . . .	3,148,000	2,930,000	+ 218,000
Beans . . .	212,000	204,000	+ 8,000
Peas . . .	67,000	91,000	− 24,000
Potatoes . .	7,540,000	7,605,000	− 65,000
Turnips and swedes .	24,431,000	25,314,000	− 884,000
Mangold . .	9,696,000	9,276,000	+ 420,000
Hay . . .	12,449,000	15,395,000	−2,946,000
Hops . . .	13,000	13,000	—

The following diagram shows the actual crops of wheat in the United Kingdom since 1881 (represented by the continuous line) and the fluctuations in the ten years averages (shown by dotted line). *Geographical Journal*, page 169.



PRODUCTION OF WHEAT IN THE UNITED KINGDOM, 1881-1910.

With regard to the quantity of wheat imported into the United Kingdom the Report of the Agricultural Committee of the Tariff Commission pointed out that "no other country shows so marked a decline of agriculture; no other country depends to so large an extent upon importation from abroad

for its food supply; in no other country has the balance between agriculture and manufacturing industries been so completely disturbed to the disadvantage of agriculture."

Italy, which comes next to us in the list of importing nations, imports only one quarter against our four-fifths of the total breadstuffs consumed. In 1901–10 the chief sources of supply were as follows :—

TABLE XVI.

	Million bushels.
India	27
Canada	26
Australia	15
United States	68
Argentina	34
Russia	29
Roumania	3
Austria-Hungary	1

Supplies are now drawn more from British sources than was the case twenty years ago. It may be pointed out that the decrease per cent. of imported wheat, including flour, in the first twelve months of war (1914–15) was 1·39 per cent. as compared with the corresponding twelve months in 1913–14, while the total weight of all foodstuffs imported increased by about 0·2 per cent.

The chief causes of the reduction in the acreage devoted to wheat in the United Kingdom appears to be, first, that corn-growing requires more capital than stock-raising or dairy-farming, and, secondly, that it involves more risk. In a Report on the Agricultural Output of Great Britain issued in 1912 by the Board of Agriculture the gross yield of culti-

vated land (arable and grass) in Great Britain in 1908 was put at £4 10s. per acre. The average yield of the corn crops comes to about £6 10s. per acre, while from wheat alone the gross yield is £8 per acre. Thus wheat gives a very decidedly higher yield than grass, even when the price per quarter amounts, as in 1908, to only 32s. Wheat-growing, moreover, produces by-products—bran, pollard, middlings, etc.—which enable pig-keeping to be undertaken at a considerable profit, and farmers are agreed that dairy-farming is actually more profitable on arable than on grass land. On the other hand, arable land requires more labour,[1] and the price of wheat fluctuates to such an extent that there is more uncertainty of profit in growing it than in producing meat or milk. When the prices per quarter of British corn are examined for the years 1885–1914 it is found that the lowest it touched was 22s. 10d. in 1894, while it was up to 34s. 11d. in 1914, thus varying between wide limits. Besides the risk of low prices, the farmer always has the certainty of having to wait nearly a year for his returns.[2]

In his address to the Farmers' Club in December, 1914, the late Professor John Wrightson gave an interesting analysis of the proportion of each county in England under wheat. He showed that more than half the wheat produced in England is grown

[1] Even ten times as much, according to some estimates.

[2] Various suggestions have recently been put forward for arresting the decline of agriculture, and more particularly of arable farming, in Great Britain, and it is earnestly to be hoped that organised efforts will at once be made in this direction. The establishment of co-operative small-holding colonies, of industrialised farms working under skilled

in the twelve Eastern, South-Eastern, and East Midland counties—Beds, Berks, Cambridge, Lincoln, Norfolk, Suffolk, Essex, Kent, Sussex, Hunts, Herts and Northants—which devote from one-fourth to one-sixth of their total arable land to wheat, and may be looked upon as doing their full share. The defaulting counties are chiefly in the north and west, which are equally suited to wheat-growing. Professor Wrightson suggested the following practical means of increasing our home wheat supply: (1) Allotting about one-sixth of arable land to wheat in the following eight counties—Cornwall, Devon, Yorks, Durham, Northumberland, Cumberland, Cheshire and Lancashire—which would then be giving the same proportion as in Bedford, Cambridge, Essex and Herts. This would mean the addition of 225,000 acres. (2) Reversion to the five-course system in the remaining counties, which would give an increase of 396,000 acres. (3) An increase of the wheat area in Scotland might amount to 56,000 acres, and (4) a million acres might be deducted from the English and Welsh oat areas. Thus the total wheat area would be increased by 1,677,000 acres without touching permanent pasture. Further increases could be obtained by breaking up permanent grass land and by growing wheat twice in four-course rotations. Many objections have been raised against ploughing up pasture which has been proved to be valuable for stock feeding, but the fact remains

management, and the establishment of secondary industries, such as the manufacture of beet sugar, have all been shown, at any rate on paper, to be practicable, while there is considerable scope for the reclamation of unused and at present unprofitable lands.

that its productivity as available land would be at least two or three times that as grass land, however good. Although Professor Wrightson's figures and suggestions are undoubtedly open to criticism, and, moreover, he hardly attended to the question of increasing the produce per acre by the freer use of artificial fertilisers and by other means, there appears to be no reasonable doubt that we could at any rate very materially increase our wheat area without prejudicing the growth of other foodstuffs. Other factors, however, than the natural suitability of the soil must obviously be taken into account when the possibility of increasing our home supply is under discussion.

An increase in the yield per acre depends very largely upon the use of appropriate fertilisers, in which the British farmer has undoubtedly shown himself backward in the past. Although the production of ammonium sulphate in 1914 very greatly exceeded that of previous years, amounting to 421,000 tons, a large proportion of it was exported, although it could have been used much more advantageously in Great Britain. The exports reached 250,000 tons in 1916, and this in spite of the fact that the Sulphate of Ammonia Association had spent large sums of money in proving the value of the substance as a fertiliser. The position is the more serious because only about 25 per cent. of the amount of nitrate usually imported will reach this country in 1916, so that it would appear that the wheat crop is being most unwisely starved of its principal food requirement.

The British crop of 1916 has fallen considerably below the average of the ten years 1906–15, although other crops show that the season has on the whole been remarkably productive. The world's wheat crop in 1916 was only 80·2 per cent. of that of 1915 and 94·9 per cent. of the five years' average; the deficiency being chiefly due to the failure of the crop in Canada and the United States. The need for investigation and more widely spread education on the subject of fertilisers is clearly evident; important work is now being done by botanists in studying the question of the production of new and more profitable varieties of wheat, and in this connection an artificial method of causing the wheat plant to tiller (or produce additional stems and roots) described by the Rev. E. Seeley may be mentioned. A new implement designed for the purpose is drawn along the lines of seedlings when these have formed three small blades. The tiller pushes earth from the ridges to the furrows in such a way as practically to bury the young plants. When these have again grown up the process is repeated, and finally the soil is slightly earthed up round the plants. The results are claimed to be most satisfactory. A large increase is noted in the number of ears of the tillered as compared with a control crop, and also an increase in the average length of the ears, amounting to about half an inch with spring-sown wheat incompletely treated and three-eighths of an inch with autumn-sown wheat treated by the simplest method. The rooting is much stronger, and thus the crop is prevented from lying down in bad weather.

The farmer is obliged to consider the question of selling price and cost before venturing to embark upon an increased production of wheat in place of other crops, and although the price now ruling (78s. per quarter December, 1916) would appear to be extraordinarily favourable, it must not be forgotten that the question is one of comparative and not of absolute proceeds. If there is less risk and almost as great a profit per acre to be expected from a field of oats rather than wheat, the farmer, who has suffered from low prices and a mistaken policy in the past, is not unnaturally chary about displacing the former in favour of the latter. The price he gets for his wheat depends mainly upon the price of imported corn, and it has been recognised that the establishment of a fixed price would help to keep the cost of the country's food supply at a steady level. In the case of wheat this price has been fixed at 60s. per quarter, and similar regulations are to be made about other cereals and feeding-stuffs. The cost of production necessarily differs very largely in different regions. All expenses have materially increased, and some requisites such as fertilisers and agricultural machinery are procurable with difficulty. The labour problem has become acute in many districts, and as yet very little organised attempt has been made to solve it, so that the prospects of the crop of 1917 in Great Britain are gloomy. Owing to bad weather not more than three-eighths of the usual area was sown in the autumn, and although something can be done in the spring towards making up the deficiency, it is computed

that spring-sown wheat yields on an average only 20 to 24 bushels per acre, while from an average autumn-sown crop 30 bushels may be expected. Only certain varieties are suitable for spring sowing —such as Red Marvel, or April Bearded—and much loss may be incurred if the variety is not judiciously selected.

Turning from the question of the wheat supply in Great Britain to that of the whole world, it may be pointed out that Professor Dickson in his Presidential Address to the Geographical Section of the British Association for the Advancement of Science in 1913 estimated that the earth might be able to supply permanently 1,000 million wheat-eaters if the average yield was increased to 20 bushels per acre. The average wheat harvest would have to be 6,000 million bushels, whereas in the decade 1901–10 it amounted to 3,233 million bushels. This last figure represents an increase of 1,322 million bushels on the figures given in my Address for the season 1897–98. The following table has been compiled from statistics of the Board of Agriculture and the Bulletins of the International Institute of Agriculture. The figures are calculated from the total wheat and rye crop, allowing 31 per cent. of the crop for rye.

TABLE XVII.

Wheat Crop for the Year 1912–13.

	MILLION BUSHELS		MILLION BUSHELS
Russia	1,280	India	245
Germany	416	Australia	71
Austria-Hungary	277	New Zealand	4
France	253	United States	531
Belgium	24	Argentina	115
Servia	10	24 other countries	515
Italy	135		
United Kingdom	39	TOTAL	4,065
Canada	150		

The average yield of wheat per acre in the decade 1901–10 for the different countries is shown in the following table. When it is compared with Table IV. page 10, it will be noticed that there is a decided increase in yield, except in the cases of Denmark, Roumania, and Argentina. In all probability the return for 1896 for Denmark, which gave 40 bushels, was somewhat exaggerated.

TABLE XVIII.

Average Yield of Wheat per Acre in

	BUSHELS		BUSHELS
Denmark	35	Austria-Hungary	18
Belgium	35	Roumania	17
Holland	33	United States	14
United Kingdom	32	Italy	13
New Zealand	31	Argentina	11
Germany	29	Australasia	11
Scandinavia	27	Russia in Europe	10
France	20	Algeria	10
Canada	19	India	11

The discussion of the possibilities of largely increasing the world's wheat supply occupied the next part of the Address. With regard to the United

States a very comprehensive study of the problem is to be found in the *Geographical Journal* for April and May, 1912 ("The Climatic Limits of Wheat Cultivation, with Special Reference to North America," by Dr. Anstead). The main conclusions which Dr. Anstead draws from his inquiry into the limits of wheat cultivation set by climatic conditions in North America are, first, that the total acreage under wheat may be very greatly increased by extension into the colder parts of Canada and into the drier parts of Canada and the United States, and, secondly, that more scientific methods may greatly increase the yield per acre. He regards it as quite possible that nearly 2,000 million bushels may in the future be produced by almost equal shares by the United States and Canada. But the population of the United States will almost certainly continue to increase rapidly, and the fear expressed in the Address that the export of wheat from the United States will cease seems likely to be realised.

The following table (reproduced from Dr. Anstead's paper in the *Geographical Journal*) shows the percentage of the total harvest exported in three decades, and it appears by no means improbable that in the not very far distant future the United States may consume all its own wheat.

TABLE XIX.

Percentage of Harvest Exported from the United States.

1881–1890 . . .	27
1891–1900 . . .	32
1901–1910 . . .	19

In Russia the corresponding percentage has fallen from 27 to 23 in the same period, and the proportion is likely to continue to get smaller as the population increases, and also the consumption per head. The yield per acre increased from 8·2 bushels in the first period to 10 in the last. As yet, as I forecasted, there has been no direct export of wheat from Siberia to other countries. With regard to Canada the estimate of six million acres in the next twelve years has been accurately fulfilled, while the percentage of harvest exported has risen to 38. The following table shows the actual increase.

TABLE XX.

DOMINION OF CANADA.

Period.	Area	Produce				Net Exports.		Consumption.	
	Sown with wheat.	Per acre.	Total.	Required as seed	Wheat and flour.	Percentage of harvest exported	Percentage of flour in net exports	Total (as food)	Per head
	Million Acres	Bushels	Million bushels	Million bushels	Million bushels			Million bushels	Bushels
1881–90	2·3	16	38	3	2	7	0.	33	7·2
1891–00	3·1	18	55	4	13	24	20	38	7·3
1901–10	5·9	19	110	9	42	38	19	59	9·4

As before stated, a great extension of the area under wheat in Canada may be expected in the future, but the estimate of 500,000,000 acres of profitable wheat land, spoken of in the Address, remains, and will remain, unrealised. Austria-Hungary in the decade 1901–10 was forced to import 1 per cent. of her total supplies, while in 1881–90

she exported 7 per cent. The prophecy that she would soon enter the ranks of importing nations was fulfilled perhaps sooner than was expected in 1898. Germany in 1901–10 imported 36 per cent. of her supplies against 16 per cent. in 1881–90. With regard to Argentina the prophecy made in the Address has not been altogether fulfilled, although the acreage has been doubled as forecasted. There are indications, however, that both the acreage and the yield per acre may be very considerably increased. The decline in the wheat harvest in India which was observed in 1891–1900 ceased, and there was an increase in 1901–10, the percentage exported again reaching its old level.

The general conclusion which may be drawn from these data appears to be that the extension of the wheat-growing area is nearing its limits and more intensive cultivation must be the means to ward off the crisis.

The possibility of raising the average yield of wheat per acre over the whole cultivated area—at present amounting to only 13 bushels, while the highest obtained in any country is about 35 bushels (although yields up to 50 bushels have been obtained in this country, and it is said that 30 quarters may be obtained by hand cultivation)—depends mainly upon the use of artificial fertilisers, especially nitrogenous compounds, and careful inquiry must be made into our available sources of such compounds, for which there is a rapidly increasing demand, and not for agricultural purposes only. As I pointed out in 1898, the most important source

of supply is Chile saltpetre, the export of which is shown in the following table.

TABLE XXI.

Export of Chile Saltpetre.

1830	1,000 tons	1904	1,497,000 tons
1850	25,000 ,,	1906	1,732,000 ,,
1890	1,000,000 ,,	1908	2,052,000 ,,
1900	1,454,000 ,,	1910	2,324,000 ,,
1902	1,379,000 ,,	1911	2,449,000 ,,

The export fell off largely in 1914 and the first six months of 1915, but then increased again very considerably. The total production and export from 1913 to 1916 is shown in the following table, taken from a bulletin of the International Institute of Agriculture.

TABLE XXII.

Summary of Production and Trade of Chilean Nitrate.

	1916. First six months.	1915.	1914.	1913.
	Metric Tons.			
Production	1,488,792	1,763,639	2,464,427	2,773,552
Export	1,356,029	2,031,014	1,847,586	2,739,530
Consignments for consumption	*730,417	*860,778	2,248,976	2,556,973
Visible stocks	(1)919,102 (30 June)	*991,304 (31 Dec.)	*1,190,078 (31 Dec.)	1,772,161 (31 Dec.)

* Incomplete data. (1) Chilean Coast only.

It is difficult to form a trustworthy estimate of the amount still available, but at any rate it is certain

that sooner or later the beds must be exhausted. Large quantities of ammonium compounds are obtained by the distillation of coal, the world's production in 1913 (the last year for which complete data are available) being 1,389,520 metric tons, and the nitrogen contained in peat has recently been recovered and utilised in the form of an ammonium salt by a process which will be described later. All these sources of supply, however, will in the not very far distant future be insufficient to meet the constantly increasing demand for combined nitrogen, and the solution of the nitrogen problem is to be found in the fixation of atmospheric nitrogen, which since the time of my Address has been effected upon a commercially successful scale. The processes which have been perfected may be classified as follows :—

(i) Those in which nitrogen and oxygen combine directly.
(ii) Those in which nitrogen is fixed by means of carbides.
(iii) The fixation of nitrogen by metals.
(iv) The preparation of synthetic ammonia.

(i) *The Direct Union of Nitrogen and Oxygen.*

The union of nitrogen and oxygen takes place with absorption of heat, and hence can be effected only if the temperature is kept high. In the Birkeland and Eyde process—the oldest employed commercially—an alternating arc flame is made to assume

a circular shape by the action of an electro-magnet. Air is led into the flame, and the exit gases are rapidly cooled from a temperature of 5000–6000° F. to 1800–1900° F. The electrodes are made of copper tubing, and are cooled by a current of water passing through them. The nitric oxide produced is allowed to combine with free oxygen to produce nitrogen peroxide, which passes up an absorption tower, where the greater part is converted into nitric acid by a stream of water; the residual NO is absorbed in other towers by means of a solution of caustic soda, sodium nitrite being thus produced. The nitric acid obtained in the first tower is converted into calcium nitrate and sold as Norwegian saltpetre, or into ammonium nitrate. The Schönherr and Pauling processes resemble Birkeland and Eyde's in essentials, but the arc is respectively circular and fan-shaped. The direct union of nitrogen and oxygen can also be brought about by burning gas under pressure, small quantities of nitric oxide being thus produced. In the Beudes process natural methane gas is used for the purpose, while in the Hausser process coke oven gas is exploded under pressure with oxygen, giving a small yield of nitric oxide. The gases are first compressed separately, passed into a bomb, exploded, and immediately cooled. The consumption of power is considerably smaller than in any process involving the use of electricity, and apparently it will be found possible to increase the yield materially by adding a larger proportion of oxygen to the air. The process will enable an otherwise wasted surplus of coke to be turned to

good account, and natural gas or crude oil can be substituted for coke oven gas.

(ii) *Fixation of Nitrogen by Carbides.*

When nitrogen gas, obtained from the atmosphere by the Hinde or other process, is passed over heated calcium carbide, calcium cyanamide, NC.NCa, is produced, carbon being separated. The carbide, made from lime and Welsh anthracite, is first ground in air-tight vessels, and screened and graded. The nitrogen gas is absorbed at a temperature of about 800–900° C., much heat being evolved in the process. The product, which contains about 60 per cent. of calcium cyanamide, is ground, and sold under the name of nitrolin. It can either be used directly as a fertiliser or can be converted into ammonia by the action of superheated steam. This process requires a cheap source of electric power, and has been worked successfully in Norway, where water power is abundant and cheap. Since certain objectionable qualities attached to the original product have been removed, nitrolin has taken its place as a valuable nitrogenous fertiliser.

(iii) *Fixation of Nitrogen by Metals.*

A process which has been successfully worked in France is that due to Dr. Serpek, in which raw bauxite (natural aluminium oxide containing about 20 per cent. of iron oxide) is first reduced in an

electric furnace, yielding a ferro-aluminium alloy. This is then heated to a temperature of about 1800° C. in an atmosphere of nitrogen, when aluminium nitrite is formed. When this is boiled with water or treated with steam under pressure it gives up all its nitrogen in the form of ammonia, and pure alumina, which can be used for the preparation of the metal, is obtained as a highly valuable by-product. Baryta can also be used for the fixation of nitrogen, and in presence of carbon it has been found to absorb the gas at a lower temperature than alumina. The barium cyanide thus obtained readily gives up its nitrogen as ammonia, and baryta is regenerated. This process has as yet hardly passed the experimental stage, but it seems probable that it may be worked on a commercially successful scale in the future.

(iv) *The Preparation of Synthetic Ammonia.*

It has long been known that in certain circumstances nitrogen and hydrogen will unite when a spark is passed through a mixture of the two gases; the amount of ammonia produced is exceedingly small, and the action is reversible. The proportion of ammonia can be greatly increased by compressing the mixed gases, and a comparatively low temperature is favourable to the reaction. In the Haber process, which has been worked successfully on a large scale by the Badische Anilin- und Soda-Fabrik, the two gases are induced to combine by the presence of a catalyst the exact nature of which is at present

not known. Osmium, uranium, and iron have all been experimented with for the purpose, but many failures (caused by the poisoning of the catalyst) were experienced before success was finally achieved. The mixed gases, which have to be obtained in a very pure state, are subjected to pressures of from 150 to 200 atmospheres, and are passed over the catalyst heated electrically to a temperature of almost 500° C. The exit gases are passed through a freezing mixture, by means of which the ammonia is liquefied, and the uncombined nitrogen and hydrogen are then again passed over the catalyst. The ammonia can be converted either into ammonium sulphate or into nitric acid by oxidation. The advantages of the Haber process are many, the chief being that it does not require a cheap source of electricity. It has recently been very rapidly developed in Germany, the yield, according to some estimates, being already about 300,000 tons of ammonia per annum, or 1000 per cent. of the yield in 1913. The output in 1917 will probably reach 500,000 tons. The successful working of the process has enabled Germany to produce the requisite quantity of nitrogenous fertiliser, and has also provided some of the vast amount of explosives she has used. The details of the Haber process are kept secret, and the German Government is backing the enterprise in the hope of being able in the future to control the market in nitrogenous substances.

A method of fixing atmospheric nitrogen discovered by Thorssell, and depending only upon chemical reactions, has recently been worked in

Sweden, but no details of the process are available. The products are ammonia, ammonium nitrate, cyanide compounds, saltpetre, and sulphuric acid, and the Swedish company will shortly be able to place them upon the market.

The impossibility of removing by mechanical means the water present in natural peat has hitherto militated against the employment of peat for obtaining producer gas and the recovery of the ammonia from it. This difficulty was overcome in Germany by an electrical method. It was discovered that the water is present in the colloidal state in peat slime or in very wet bogs, and consequently when a high voltage current is passed through cataphoresis occurs, and a firm mass of peat is obtained. A process for the same purpose has also been satisfactorily worked in Scotland. The wet peat is passed through iron tubes heated to a moderate temperature, and the colloidal compound is thus decomposed. The mass is then pressed into cakes, which can be used for gas production. The nitrogen can thus be recovered in the form of ammonium sulphate.

In France, cyanamide is for the present reserved exclusively for Government purposes, and none will be available for agriculture next spring. The output of Norwegian nitrate of lime has also been much reduced. The following table (from a bulletin of the International Institute of Agriculture) gives the imports and exports of nitrogenous fertilisers since 1913.

TABLE XXIII.

Imports and Exports of Synthetic Nitrogenous Fertilisers : (a) nitrate of ammonia ; (b) nitrate of lime (Norwegian) ; (c) cyanamide.

Country.	Years.			First six months.		
	1915.	1914.	1913.	1916.	1915.	1914.
	Metric tons.					
Import.						
Germany . .	(i)	(i)	78,257	(i)	(i)	31,038
Denmark . .	(i)	(i)	5,066	(ii)	(ii)	(ii)
France (*b* and *c*).	2,458	3,809	10,010	4,914	1,426	1,531
Russia . . .	0	1,360	2,326	0	0	11,360
Sweden (*a*) . .	0	101	62	(ii)	(ii)	(ii)
,, (*b*) . .	0	3	24	0	(ii)	(ii)
Canada (*a*) . .	*437	*907	*1,167	(i)	(i)	(i)
United States .	(ii)	(ii)	14,891	(ii)	(ii)	(ii)
Algeria (*c*) . .	4	487	1,091	0	0	438
Egypt (*c*) . .	0	771	971	(ii)	(ii)	(ii)
Export.						
Germany . .	(i)	(i)	30,463	(i)	(i)	22,440
France (*b* and *c*).	64	373	839	109	0	320
Norway (*a*) . .	26,459	11,959	9,107	20,407	9,177	6,011
,, (*b*) . .	38,168	75,176	79,927	27,710	22,742	31,200
,, (*c*) . .	24,787	13,720	22,111	12,505	13,476	10,355
Sweden (*c*) . .	16,553	4,755	16,913	9,487	(ii)	(ii)

(i) Data not available.
(ii) Corresponding statistics unavailable.
* Twelve months ending 31st March.

The foregoing brief accounts of recent work on the fixation of atmospheric nitrogen show how the discoveries of the chemist and the engineer have been applied to the solution of the problem of the raising of the world's average of wheat production per acre. The extension of scientific knowledge will no doubt lead to a wider use of artificial fertilisers by the British farmer, who is at present credited with a reluctance to take the fullest advantage of

them. Much research work is waiting to be done on the most economical methods of using manures; thus the relationship between the efficiency of fertilising action and rotation has yet to be thoroughly elucidated, and the question of the sickness of the soil requires investigation in detail.

There is need also of systematically spreading a knowledge of the possibilities of increasing yield by the judicious use of fertilisers, and of the limits set by natural conditions to their favourable action. The following table (from "Soils and Manures," by Dr. E. J. Russell) shows striking differences of yield on good and poor wheat soils, and the effects of manuring are apparent, although the naturally good soil always has the advantage over the poorer soil.

TABLE XXIV.

Yield of Wheat from Various Soils. Bushels per Acre.

	Good wheat soil.	Soil less suited to wheat, Rothamsted.		
	Sussex brick earth.	Un-manured.	Dung.	Artificial manures. Very heavy dressing.
Good years: 1885	54	15	40	37
1887	50	15	35	35
1899	53	12	43	59
Bad years: 1879	32	5	16	21
1892	27	9	33	38
Average of 5 years:				
1900–1904	44	10	33	39
1905–1909	42	13	38	41

There is necessarily a limit to the beneficial results obtained by manuring, and the application

of fertilisers above and beyond this limit may not merely be useless but positively harmful; thus it is known that the use of too liberal a quantity of nitrogenous manure renders the crop more liable to disease owing to the thinning of the cell-walls. A series of field trials carried out in Ireland conclusively proved that a mixture of artificial fertilisers and farmyard manure gives the most satisfactory results. No practical method of storing farmyard manure so that the loss of ammoniacal nitrogen is reduced to a minimum or altogether eliminated has yet been discovered, although it is known that storage in perfectly air-tight tanks has the desired effect, while providing adequate shelter from the weather for the manure heap has decidedly beneficial results. The question of the loss of nitrogen has been studied recently by Dr. Russell and Mr. Appleyard. Two manured crops were selected, and one was allowed to lie fallow, while the other was cropped, and the amount of nitrate in the soil was determined at intervals of ten days. It was found that in both plots accumulation of nitrate occurred up to the middle of September, the fallow plot then containing per 18 in. depth of soil 170 lb. of nitric nitrogen per acre. The fields then began to lose nitrate, until in February the fallow plot contained only 50 lb. per acre, having lost an amount equivalent to 7 cwt. of sodium nitrate. The cropped plot in the same time lost as much nitrogen as is contained in 24 lb. of wheat and the corresponding quantity of straw. The loss on the fallow plot might have been very considerably lessened by

planting a quick-growing crop and then feeding it off or ploughing it in, and these experiments clearly show the value of spring dressings of nitrogenous manures. Sodium nitrate can advantageously be used for wheat at the rate of 1 cwt. per acre, and is best applied as a top dressing in two or three instalments. Calcium nitrate closely resembles sodium nitrate and appears to be preferable for heavy soils. The calcium nitrate recently put upon the market is a decided improvement upon the first samples, which were very hygroscopic and troublesome to use. Calcium cyanide or nitrolin has the advantage of being insoluble in water, and is hence not readily washed out of the soil. It is slowly decomposed by the bacteria in the soil, giving off ammonia, and hence it is best applied at the time of sowing, to give time for the decomposition to occur. Ammonium sulphate can be used at the rate of about 1 cwt. to the acre, and the Rothamsted experiments showed that it is rather better manure for barley than sodium nitrate, giving an equal yield and a better quality. For wheat sodium nitrate is generally preferable. Ammonium sulphate has a tendency to make the soil acid when applied alone, and thus hinder plant growth; hence it may conveniently be used with sodium nitrate, which has the opposite effect. Sodium nitrate sinks more readily into the soil, and thus encourages deep roots in the plant. The comparative effects of different nitrogenous manures are shown in the following table.

TABLE XXV.

ROTHAMSTED: *Yield per Acre*, 1909–1912.

—	Barley, 1909		Wheat, 1910		Mangolds	
					1911	1912
	Little Hoos		Little Hoos		L. Hoos	L. Knot Wood
	Grain	Straw	Grain	Straw		
	Bush.	Lbs.	Bush.	Lbs.	Tons.	Tons.
No Nitrogen . .	28·7	2,619	15·4	1,526	9·8	11.5
Nitrate of Soda . .	48·1	3,882	27·0	3,760	15·4	18·4
Sulphate of Ammonia	49·1	3,517	24·6	2,964	11·8	—
Cyanamide . . .	45·2	3,976	22·4	2,343	11·1	—
Nitrate of Lime . .	46·2	4,449	20·6	3,618	12·7	18·4

The time is ripe for an exhaustive stocktaking of the food resources of the British Empire and for the planning of a scheme for developing agriculture upon a scientific basis. It is realised at last that the production of our own food supply is a matter of the greatest moment. Events have shown us that it is not a question of the profit to be obtained by importing wheat or growing, as some of my critics seemed to imagine. Increased agricultural activity has a much wider significance for the welfare of the nation than as a factor, important though it is, in adding to the national wealth, and intimately connected with the problem are economic questions of labour, distribution of population, and transport. The detailed discussion of these does not lie within the scope of this book, but the public is showing signs of awakening from its state of apathy concerning

agricultural science, and recent events have tended to direct our attention to questions of the world's resources as well as our own. A heavy responsibility rests upon the scientific man of the present generation, of which the student of one hundred years ago had barely an inkling. Then the earth's stores of latent energy appeared to be illimitable; now we realise that the exhaustion of some of them is within sight, and that all our faculties must be turned to the problems of utilising them most economically, and at the same time spreading abroad knowledge and a heightened sense of the importance of improving the condition of agriculture in our own country by the employment of more scientific methods.

The value of the articles by Mr. C. Wood Davis and the Hon. John Hyde, that appeared in an earlier edition appears to be justified, and I propose to supplement some of their statistics by more recent data and to make some comments, based upon fresh work, on their statements and conclusions.

The rapid increase in the world's bread-eaters has continued in the twentieth century, and the increase in the area devoted to wheat-growing has not by any means kept pace with it. The total wheat area in the world in the decade 1881–1890 was estimated at 192 million acres, while in the decade 1901–10 it has risen to 242 million acres, an increase of 26 per cent. The increase in North America in the same periods was from 40·6 to 54·3 million acres, or 33·7 per cent., but in these figures no account is taken of any diminution in the area

devoted to the growth of any other breadstuff such as rye. The latest figures show a very decided increase over those given by Mr. Wood Davis, which is also the case with the wheat areas of Asia and South America, as shown in the following table:

TABLE XXVI.

Wheat-bearing Areas.

	(i) 1883–4	(ii) 1898–9	(iii) 1901–10	Increase (ii) over (i)	Increase (iii) over (ii)
Million Areas—					
Canada . .	2·4	3·2	5·9	0·8	2·7
Australasia . .	3·2	4·5	5·9	1·3	1·4
Argentina .	1·4	6·1	12·0	4·7	5·9
Siberia . .	2·0	3·3	*14·3	1·3	11·0

* Russia in Asia.

This table seems to indicate that the increase in area is nearing its limit, which, however, does not appear to have been reached yet. When the quantity exported from the United States is investigated a very disquieting decrease is brought to light. Thus, while in 1881–90 the percentage of the harvest exported was 27, and in 1891–1900 it had risen to 32 per cent., it fell in the following decade 1901–10 to 19 per cent., showing clearly that the time is not far distant when the United States will consume nearly, if not quite, all her own harvest. In Canada in the same periods the percentage exported shows an enormous increase.

The part taken by America in supplying the world with wheat is adequately and very judiciously dis-

cussed by the Hon. John Hyde, whose estimates and conclusions have been remarkably borne out by facts. The average harvest for the Dominion of Canada and the United States in the decade 1901–10 was 767 million bushels, while in 1914 it amounted to 1,051 million bushels. Enormous as the increase is, it must be remembered that the total consumption in the United States in 1901–10 amounted to nearly 146 per cent. of that in 1891–1900, and thus appears to be approximately keeping pace with the increase of production.

The climatic limits of wheat cultivation, with special reference to North America, have been discussed very comprehensively by Dr. T. F. Anstead in the *Geographical Journal* for April and May, 1912, in an article to which allusion has already been made. The total amount of heat required by any plant to attain full development depends upon two factors: (i) The temperature to which it is exposed; (ii) the time over which this temperature extends. The accumulated temperature in day degrees has been determined by accurate observations, a day degree being the number of degrees by which the mean temperature exceeds 5° C. for a period of one day. In South-East England the accumulated temperature for wheat ripening has been found to be about 1100° C. When the accumulated temperature required in other regions is investigated it is found that it bears a relationship to the mean temperature of the region, and it is also influenced by another factor, the mean duration of light. If the "index number," *i.e.*, the sum of the

mean duration of darkness and the mean temperature, is taken, a striking relationship is obtained. This is shown in the following table and diagram (from the *Geographical Journal*, Vol. xxxix, No. 4, pages 356 and 357).

TABLE XXVII.

Locality.	Accumulated temperature.	Mean temperature.	Duration of light.		Duration of darkness Mean.	Index of mean temperature plus mean darkness.
			Total.	Mean.		
	deg. C.	deg. C.	hrs.	hrs.	hrs.	
Copper Centre, Alaska	734	12·6	1,771	18·4	5·6	18·2
Sitka, Alaska . .	841	11·1	2,232	16·3	7·7	18·8
Dunvegan, Canada .	930	12·6	2,012	16·5	7·5	20·1
Vermilion, Canada .	948	13·5	1,898	17·0	7·0	20·5
Chippewyan, Canada .	974	12·9	2,030	16·5	7·5	20·4
Nappan, Canada . .	1,093	14·7	1,676	15·0	9·0	23·7
South Vologda, Russia	1,100	16·0	1,750	17·5	6·5	22·5
Agassiz, Canada . .	1,120	14·3	1,879	15·4	8·6	22·9
Kostroma, Russia .	1,135	16·6	1,668	17·0	7·0	23·6
Ufa, Russia . . .	1,157	16·3	1,684	16·5	7·5	23·8
Viatka, Russia . .	1,171	17·1	1,628	16·8	7·2	24·3
Fargo, U.S.A. . .	1,191	16·7	1,566	15·4	8·6	25·3
North Simbirsk, Russia	1,251	17·8	1,628	16·6	7·4	25·2
Indian Head, Canada .	1,293	15·3	1,960	15·6	8·4	23·7
Bozeman, U.S.A. .	1,293	15·4	1,887	15·0	9·0	24·4
Brandon, Canada .	1,294	15·8	1,862	15·8	8·5	24·3
Poltava, Russia . .	1,297	16·7	1,726	15·5	8·5	25·2
Ottawa, Canada . .	1,330	17·3	1,624	15·0	9·0	26·3
Don Territory, Russia.	1,387	18·0	1,648	15·4	8·6	26·6
South Samara, Russia.	1,390	19·4	1,562	16·1	7·9	27·3
Veronezh, Russia .	1,406	18·1	1,711	16·0	8·0	26·1
Bessarabia, Russia .	1,436	18·0	1,669	15·2	8·8	26·8
North Taurida, Russia	1,469	16·9	1,829	14·9	9·1	26·0
St. Paul, U.S.A. . .	1,509	17·3	1,813	14·9	9·1	26·4
S. Kherson, Russia .	1,547	17·6	1,868	15·2	8·8	26·4

From these results the following general statement is deduced, the effects of summer pests being neglected: "Wheat cultivation is possible at stations where the degrees of accumulated temperature,

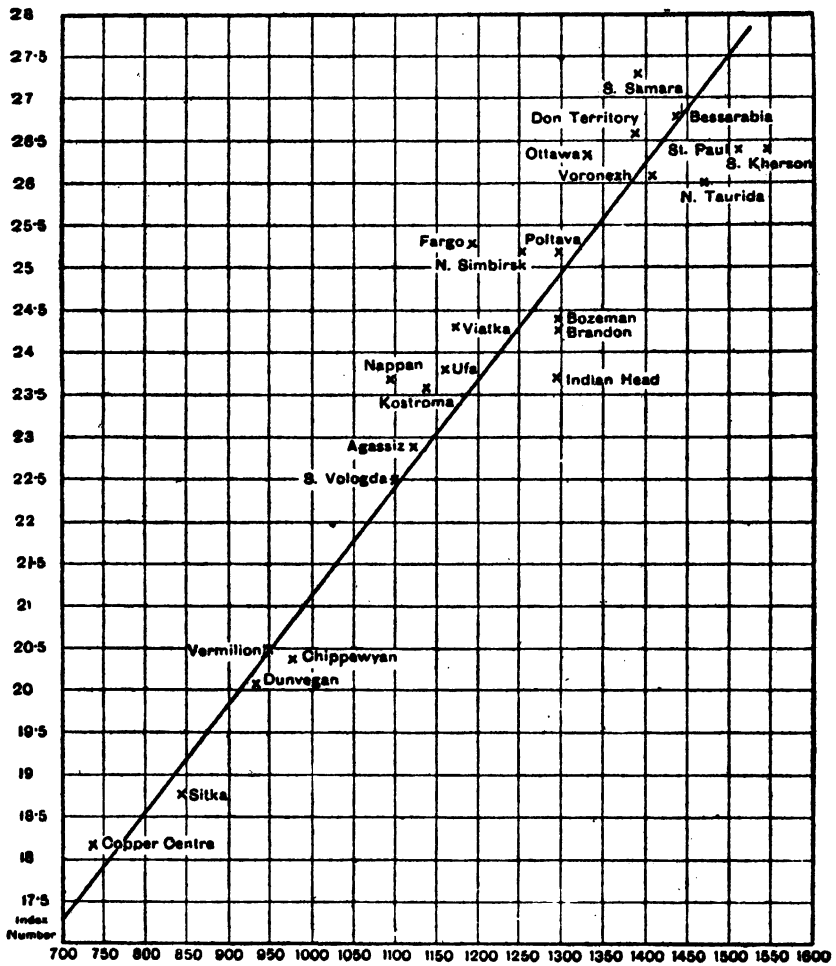


FIG. 3.—DIAGRAM SHOWING THE RELATION BETWEEN THE ACCUMULATED TEMPERATURES REQUIRED FOR WHEAT AND THE INDEX NUMBERS OF MEAN TEMPERATURE PLUS MEAN DURATION OF DARKNESS DURING THE PERIODS OF GROWTH.

which is experienced between the dates when the mean temperature curve rises above 5° C. in spring

and descends to 10° C. in autumn, amount to the number indicated by the straight line in the diagram as that required under the conditions of mean temperature and duration of light during the same period at the respective stations."

The conclusions naturally apply only to known breeds of wheat, but they are particularly valuable as providing a means of forecasting the possibility or otherwise of growing wheat in regions which have not yet been used for the purpose. It appears that the Canadian territory between Manitoba and Lake Superior is too cold for wheat cultivation, and thus separates the two great wheat-growing districts of the Dominion. As regards the limits to wheat cultivation set by rainfall, which is the conditioning factor in the central and southern portions of North America, it has been shown that the methods known as dry farming and the use of drought-resisting varieties have enabled the semi-arid regions to be employed for wheat-growing. In countries in which the climate is of the Mediterranean type, *i.e.*, having a relatively mild winter and rain in the cooler parts of the year, a rainfall of 10 inches is sufficient, and in specially favourable conditions one or even two inches less may be enough. A mean annual rainfall of 11 inches is adequate over the northern portion of the great plains of the United States. This means to say that wheat cultivation may be extended into the drier regions of both Canada and the United States, and though the yield per acre may remain less than in more favoured regions, it may, even so, exceed the average at present obtained.

Although modern agricultural methods have possibly deferred the time when the wheat problem becomes of extreme urgency, the fact still remains that sooner or later a deficit in wheat must arise which will be met only by the more extended manufacture and use of artificial fertilisers of a nitrogenous nature. "Starvation will be averted through the laboratory," and the intelligent application of the results obtained by the work of the botanist and chemist will provide an assured future for the millions of bread-eaters in the world. Eighteen years ago I wrote, "We eagerly spend millions to protect our coasts and commerce; and millions more on ships, explosives, guns and men; but we omit to take necessary precautions to supply ourselves with the very first and supremely important munition of war-food." The vast amount which this expenditure has now reached was then utterly unforeseen, and had I prophesied that it would touch 2,000 millions per annum the outcry of my critics would probably have been even louder than it was. It is to be hoped that now at last the necessity of providing ourselves with the first munition of war is understood, and a workable and economically sound scheme for the purpose will be organised.

FUTURE WHEAT SUPPLIES

By Sir Henry Rew, K.C.B.

The meeting of the British Association in 1898 is memorable by reason of the fact that the Presidential Address was devoted to an examination of the problem of the future of wheat cultivation in the world. The argument which Sir William Crookes then developed attracted widespread attention, and, as commonly happens, it became a good deal distorted in public discussion. One or two arresting statements which he placed in the forefront of his Address, such as "All civilised nations stand in deadly peril of not having enough to eat," created an impression that a fiat of doom had been pronounced by a leader of science, and that the world was destined to come to an end within half a century by a process of lingering starvation. The British public, however, while they receive prophecies of disaster with avidity, forget them with equal alacrity. One reason, indeed, why the Briton is a psychological enigma to friends and foes alike, is that he constantly predicts disaster and never believes in it. He is a confirmed pessimist in words, and an inveterate

optimist in deeds. The warning which Sir William Crookes gave, and the advice which he offered—like much other warning and advice—were popularly regarded as an attempt to make our flesh creep, and the vision of a scarcity of food was treated by the nation at large as a dream. The dream has become a grim reality, and the British people have at last realised, under the stress of a fight for existence, that the question of food supply is the most vital of all national interests.

After nearly twenty years, Sir William Crookes has republished his Address, and has added a review of the progress of events in the interval. To some extent, the review is reassuring, inasmuch as the area of wheat cultivation has shown greater elasticity than was assumed. The estimate of total possible expansion made in 1898 had already been exceeded in 1914, and the War has revealed possibilities of still further additions in all wheat-exporting countries. The moral of the statistics presented in 1898 was that the chemist must come to the rescue, and that by the aid of science the production of the wheat-growing lands of the world could be greatly increased. Sir William Crookes now shows that the chemist has come to the rescue, and that although there may be a limit to the land suitable for growing wheat, and also to the quantity of stored-up natural fertilisers, there is practically no limit to the resources of nitrogen which science can place at the service of agriculture.

For many years past it has been my business, and for a still longer period my hobby, to deal with

questions of food supplies, and I have taken every opportunity to emphasise the fact that international statistics of crops—and still more of live stock and produce—must be discussed with a lavish allowance for probable error. Much has been done by the International Statistical Institute and, later, by the International Agricultural Institute to improve and co-ordinate the statistics of agricultural production, and in nearly every country which is of importance in the world's exchange of foodstuffs the systematic collection of agricultural statistics is now recognised as a national service of primary importance. The demand of the public for statistics of food supplies has been insistent since the War began, but it is not realised that such figures are only available where there is a complete and carefully organised machinery for collecting them. Fortunately, in this country machinery has for many years existed at the Board of Agriculture, mainly in consequence of the persistent pressure of a few—among whom my old friend and colleague, Major Craigie, C.B., was foremost—who induced reluctant Governments to provide exiguous means for establishing a system which, though still imperfect, provides a basis for calculating the food resources of the United Kingdom with a fair degree of accuracy. The British Isles, however, from the statistician's point of view, present a very simple proposition, and nothing but the comparatively trifling cost prevents the establishment of a statistical service which would provide complete and detailed statistics of the production of every acre. But in the larger countries of the world, where square miles are as

acres here, it is a more difficult as well as a more costly matter, and a compilation of the returns from every country must obviously embrace statistics of very varying degrees of accuracy.

Of all international agricultural statistics, those of wheat acreage are, happily, the most complete and the most trustworthy. The latest estimates, made by the International Agricultural Institute (for 1913–14), give 273,000,000 acres as the total area under wheat in the world, and it may be reckoned that this is probably accurate within 10,000,000 one way or the other. But, in the nature of things, it is easier to obtain reliable returns of area than of crops. The yield of a crop can only be estimated, and it is evident that a small error in the estimate of the average yield per acre makes a large difference in the total production from millions of acres. For wheat-exporting countries, the trade returns afford, over a series of years, a good test of the crop estimates. It is indeed fortunate for the statistician, who is so frequently called upon to produce bricks without straw, that every nation is compelled, for its own purposes, to obtain returns of the quantities of all commodities leaving or entering its ports. If the home demand remains constant, or is increased only in proportion to increased population, the estimates of the total crop may be checked by the quantity exported. This test can, however, only be applied some months—in most cases a year—after the crop is harvested, and unusual economic conditions may render it unreliable.

If statistics of crops harvested can only be

approximately accurate, forecasts of future crops are obviously much more speculative. Every year forecasts are made by the corn trade of the probable supplies during the ensuing cereal year, which for general purposes is usually reckoned as beginning on August 1st, although for calculations of available supplies for this country I have usually adopted the year beginning September 1st, by which date a fairly trustworthy opinion of the outturn of the home crop can be formed. Since the outbreak of war, the normal difficulties of making such forecasts have been greatly aggravated, while their importance, not only to the United Kingdom, but to France and Italy, was immensely increased. In August, 1914, it was necessary to make a careful calculation of the probable supplies of wheat during the next twelve months, a calculation which had to be revised when the Dardanelles were closed. By that time, there was no possibility of an increase of wheat acreage in the Northern Hemisphere, which would affect the actual supplies to meet the demands up to the next harvest. Some commercial estimates, made on the basis of previous years' figures of supply and demand, suggested that there was not enough available wheat in the world to satisfy the requirements of the wheat-importing countries, even allowing for the elimination of Germany. But such estimates did not allow sufficiently for the new economic conditions, which disturbed all calculations made on the basis of the past. From the United States and Canada, which had fairly good crops, the rise in prices drew out a larger proportion than had ever previously

been known, while India, which had time to increase her wheat acreage by 4,000,000 acres, was favoured with an unusually good crop. The measures taken by the Government to purchase and hold a certain quantity of wheat, and, in co-operation with the Government of India, to secure the early shipment of a large part of the Indian surplus, ensured a sufficiency of supplies for this country, but at the end of the cereal year 1914–15 there was very little available wheat left in the world. In 1915 the United Kingdom increased its wheat acreage by nearly 450,000 acres, Canada by 2,700,000 acres, Australia by 3,000,000 acres, and the United States by 7,000,000 acres. It was remarkable that in Canada and Australia, as in India, the extension of acreage was accompanied by exceptionally good harvests, so that the quantity available from these sources was unprecedentedly large, and supplies for the cereal year 1915–16 were ample for all requirements, and in fact only a small part of the Australian surplus was drawn upon. For 1916–17, prospects looked at first fairly favourable, owing to the large "carry-over" in Australia and India, notwithstanding that the crop in the United States and Canada was very unsatisfactory. Very pessimistic forecasts of the probable supplies from North America were made, and obtained credence. But again too little was allowed for economic factors in stimulating export, and the quantity actually shipped was nearly double that which some "experts" predicted. In this year, however, the difficulty of tonnage which had been steadily increasing became much more acute, in consequence

of the rapid development of submarine activity, and the locality of wheat supplies became almost as important as their quantity.

The following table shows, for the five main sources of wheat supply during the war, the acreage under wheat before the war, and the changes made under the influence of war conditions. The years given are those in which the crop was harvested, and the figures represent millions of acres :—

	1914	1915	1916	1917
United States of America .	53·5	60·5	57·3	59·1
Canada	10·3	13·0	12·9	13·4
Australia	9·3	9·7	12·5	12·5
India	28·5	32·5	30·1	33·0
Argentina	16·2	16·4	16·4	16·1

An addition or reduction of acreage obviously does not represent a proportionate change in the quantity of wheat grown, which is dependent mainly upon seasonal conditions. Other factors, such as the supply of mechanical or manual labour, the quality of seed, and the use of fertilisers, may affect the yield, but, as between one year and another, the benevolence or malevolence of Nature has a far greater influence than any operation of man. Over a series of years seasonal influence may be averaged, and acreage is a fair index of production, but this does not apply to single-year comparisons.

The crops in the wheat-exporting countries for each of the four years were—in millions of quarters—estimated as follows :—

	1914	1915	1916	1917
United States of America .	111·5	126·6	80·0	82·0
Canada	20·2	47·0	27·5	31·0
Australia	12·9	3·1	22·5	19·0
India	~~39·1~~	~~47·2~~	~~28·9~~	~~47·8~~
Argentina	14·3	21·1	21·6	10·0

The figures for 1917 are subject to revision, especially in the case of the United States and Canada.

Even the crop figures are not a measure of actual supplies for the needs of purchasing countries. The wheat available for export is the surplus over home consumption, and this consumption may vary within somewhat wide limits. Wheat is an excellent food for animals, as well as for man, and a certain proportion of the inferior or " tail " corn is normally not marketed, but fed to stock. If the price which the grower is offered for his wheat is not higher than that at which he can profitably feed it to his cattle, he will not sell. On the other hand, if it is sufficiently tempting, he will part with every bushel which can be used by millers, and will feed his stock on other materials.

The proportion of the harvested crop which is exported varies in normal times very greatly in each of the countries above mentioned. On the average, for the four years before the War Argentina exported 57 per cent. of her crop, Canada 46 per cent., the United States 16 per cent., and India 14 per cent. Australia stood even higher in this respect than Argentina for this particular period, but the annual fluctuations in the Australian crop are so great that

it is difficult to rely upon any average as a guide. In the cereal year 1914–15, Argentina exported 55 per cent. of her crop, Canada 54 per cent., and the United States 37 per cent. It was evident that Canada made a special effort, as she exported only 1,000,000 quarters less in 1914–15, from a crop of 20,000,000 quarters, than she had exported previously from an average crop of 25,000,000. But the effect of the exceptional drain on exporting countries during 1915 was felt in the following year, as the complete exhaustion of all available supplies—and the consequent absence of any "carry-over" for the next year—established as a first charge on the succeeding crop the restoration of home stocks. The United States, for example, although having a larger crop in 1915, was, in fact, able to spare a smaller quantity for export than she had done from the crop of 1914, while Canada, while exporting a much larger quantity, was, nevertheless, compelled to retain also a larger quantity for home demands.

The main point in regard to which the experience of war conditions may illuminate the general question of the world's future wheat supplies is the evidence of rapid response of wheat acreage to economic pressure. The five countries on which the importing countries had to rely increased their area under wheat by 14,000,000 acres, or 12 per cent., in a single year. The bounty of Nature assisted the enterprise of man, and the quantity harvested was increased by 47,000,000 quarters, or 24 per cent. In the two succeeding years, Nature withheld her assistance, and although the acreage was maintained, and in

1917 somewhat increased, the total crop was no greater than that yielded by the acreage of 1914.

These fluctuations illustrate another point. Every year, in normal times, there is a theoretical risk of a world famine of wheat. The difference between a good and a bad harvest in any country may easily vary from 25 per cent. above to 25 per cent. below an average. In the extreme cases in the United Kingdom the yield has ranged from 38¾ bushels per acre in 1863 to 15½ bushels per acre in 1879. If in any one year the wheat crop all over the world were to fail, the exporting countries might have little or none to spare, while the importing countries would require more than usual. The British Isles, if no wheat were purchasable from other countries, would obviously be in a state of famine, while even in a normally self-supporting country like France a deficiency of 25 per cent. in her home crop, without any chance of supplying the deficiency from abroad, would involve serious privation. In time of peace this theoretical risk is practically negligible. The extended range of wheat-growing is the best security against a universal failure of the crop.

On the whole, it would appear that the outlook for the maintenance of a sufficient supply of wheat for the world's demand has brightened. Just before the War, in the annual review of the world's agricultural statistics issued by the Board of Agriculture, I took occasion to summarise the latest available figures of wheat acreage, in relation to population, and the conclusions reached were briefly summarised thus :—

"The figures summarised showed that in the British Empire the increase in the acreage under wheat had been 45·5 per cent., and in population 6·6 per cent., during the ten years 1901–11. In Europe the wheat area had increased by 17·1 per cent., and population by 15·6 per cent., while in the other countries for which comparative figures could be given—Algeria, Argentina, Japan, Siberia, United States, and Uruguay—the wheat area had increased by 19·9 per cent. and population by 20·6 per cent. It was pointed out that the population of the wheat-growing countries are not all wheat-eaters, so that the comparison could not be regarded as very precise, and a calculation—if such were possible—of the increase of wheat consumers would be necessary for a complete analysis of the situation. The figures given represented that the amount of land devoted to wheat over the greater part of the world—including the main wheat areas and all the chief wheat-eating nations—had increased from about 0·28 to about 0·31 of an acre per head, and in view of the fact that on the whole the production per acre has increased the position was regarded as fairly satisfactory."

In view of the authoritative facts given as to the aid which science can render to wheat-growers in their attempts to increase the produce from their land, and in view also of the evidence, which the War has furnished, that there is a greater elasticity in the world's wheat supplies, under present conditions, than might *primâ facie* have been assumed, it would seem that, for any

period which can reasonably be calculated, the risk of an insufficiency of wheat in the world may be regarded as not in itself affording immediate cause for anxiety to the present generation.

The existence of a plenitude of wheat in the world does not, however, ensure a sufficiency for the British Isles. This question has lately taken on a new aspect. Prior to the War the position in which the United Kingdom would be placed if the free access of grain ships to its ports were impeded was regarded with serious anxiety by comparatively few. The appointment of a Royal Commission on Food Supplies in Time of War testified to the fact that the Government of the day recognised the existence of the problem, and, prior to this, a Committee formed by the late Mr. Yerburgh, with the assistance of the Central Chamber of Agriculture, had examined in some detail a proposal to establish national granaries as a security against interruption of oversea supplies. In the light of present knowledge, it is easy to condemn the neglect to make some such provision for insurance against a grave risk, as was recommended by those who regarded the risk as existent. The fact was, however, that the nation generally did not take the risk seriously. The majority of the people regarded the German menace in much the same way as they regarded the Yellow Peril, or the collision of a comet with the earth—events which were theoretically possible, but for which it was not practically necessary to make provision. Of the minority who knew that an attack by Germany was within the limits of serious probabilities, the

greater number argued that so long as we maintained the supremacy of our Fleet, and held the command of the sea, no question of the starvation of the country could arise.

During the first two years of the War those who trusted in the Fleet as a sufficient safeguard of our food supplies appeared to be justified. The interference of the enemy with our shipping was less effective than even pre-War optimists had reckoned. The rate of insurance against war risk settled down, after the first few weeks, to a figure which was an eloquent testimony to the impotence of the enemy at sea. Even those who had foreseen the activities of the submarine had underestimated the possibilities of defence against its attacks. If it was formidable, it was also found to be vulnerable, and it entirely failed in closing the narrow seas where it was expected to be found most effective. For over three years our cross-Channel lines of communication have been secured, and the daily passage of men and material has been almost uninterrupted. But the power and range of the submarine have been developed, and from a pest of the narrow seas it has become a pirate of the ocean. The under-water raider has become a menace to the world's shipping, against which it appears impossible to devise complete protection, and the supremacy of the sea appears never likely again to be secured in the old sense. That access to the British Isles can be entirely prevented is inconceivable, so long as British seamen retain the spirit of their race. No risk of attack, however deadly, or of

savagery, however fiendish, will deter them from putting to sea. But, if we are not likely to be beleaguered in a literal sense, it is clear that we may be so far besieged that the garrison should be provisioned for emergencies.

It is not possible, under any conditions short of a drastic reduction of population or an abandonment of a large part of our commerce and industries, that this country can produce from its own soil all the various food supplies which it requires. But a substantial increase in the home supply of breadstuffs is possible. To supply the existing population of the United Kingdom with bread at the normal rate of consumption requires about 34,000,000 quarters of wheat per annum, which at the present average yield would occupy nearly 9,000,000 acres. The largest acreage under wheat of which we have actual record is 3,981,000 acres in 1869. During the Napoleonic wars of a century ago the estimated acreage was 3,160,000 acres in England and Wales. There are no available figures for Scotland and Ireland at that period, but it is improbable that the total for the United Kingdom exceeded 4,000,000 acres. Trustworthy agricultural returns were commenced in 1866, and prior to that date any figures are uncertain. The reduction of wheat-growing was steadily progressive during the last quarter of the nineteenth century, and reached its climax in 1904, when the total area under wheat was 1,407,000 acres. There has been some recovery during the present century, and under war conditions the acreage reached 2,335,000 acres in 1915. If it be granted

that what has been done may again be done, there is nothing unreasonable in assuming that 4,000,000 acres of wheat may be grown in the United Kingdom on land which is suitable for its cultivation.

What are the conditions necessary to secure this acreage? This question engaged the attention of the Royal Commission on Food Supplies in Time of War, and the evidence of several representative witnesses was taken on the point. In reviewing the evidence the Commission observed:—

"It appears from the returns of the Board of Agriculture that when the acreage under wheat and the consequent production in the United Kingdom was equivalent to that which Mr. Read hopes to restore by raising prices to 40s. per qr., the price of wheat was over 50s. per qr. Mr. Rew also suggested in his evidence that to restore the acreage which has already been lost is a very different thing from maintaining it. He pointed out that farmers abandoned wheat-growing with reluctance, and perhaps held on longer than the financial position warranted; so that in order to induce them to grow the same quantity as in former years, the change of system having been made, it might be necessary to offer them a greater temptation than the price which then obtained. The opinion has also been expressed that even if prices had been maintained at their level of 20 or 30 years ago, wheat would still have gone out of cultivation, because farming has become relatively more profitable in other directions, such as dairying, the cultivation of barley, and raising and feeding of stock."

Whatever force there may be in these contentions, it is to be noted that when in 1869 farmers placed nearly 4,000,000 acres under wheat, the average price in the two preceding years had been 64s. per quarter. Even if it be allowed that increased cost of production may be set off by higher yield per acre, it would still be sanguine to assume that the wheat acreage of 1869 can be recovered under the influence of a substantially lower level of price.

Assuming, however, that 4,000,000 acres can and may be maintained under wheat in the United Kingdom, it is desirable to realise clearly the extent to which the security of our bread supplies would be thereby assured? The years 1868 and 1874 were distinguished as being two of the most bountiful harvests ever known in this country, while the harvest of 1879 was the worst in the memory of living man. The records of these years, with 1869 added as the year of maximum acreage, are as follows :—

Year.	Acreage.	Produce.	Yield per acre.
		Qrs.	Bushels.
1868 . .	3,951,000	16,730,000	34
1869 . .	3,981,000	13,420,000	27
1874 . .	3,830,000	13,970,000	29¼
1879 . .	3,056,000	5,910,000	15½

Fifty years ago 4,000,000 acres represented 13 acres, whereas now it would represent less than 9 acres, per 100 inhabitants. With a maximum yield we might reckon, at our present normal rate of

consumption, on about six months' supplies, but with a minimum yield on less than three months' supplies.

Wheat, however, as the public has now realised, is not the only possible breadstuff. When the Food Controller last January announced that it was necessary to economise bread, he also determined that it was essential to economise wheat. For the first economy he trusted the people, and his confidence, having regard to the fact that the country had the shortest crop of potatoes on record, was justified. The second economy was effected by compulsion. The consumption of wheat was reduced to the extent of over 20 per cent., with the result that it was possible to build up a reserve which should be sufficient for emergencies if the consumption of bread is not increased. Such a change in conditions which intimately affect every individual in the country could not be expected to be made without difficulties arising, both among the makers and the consumers of bread, but on the whole it is creditable to the adaptability of both classes that the period of disturbance was so short, and the unfamiliar war bread so speedily became accepted by all but an inevitable minority of inveterate "grousers."

The cereals, other than wheat, grown in this country which may be regarded as potential breadstuffs are barley, oats, rye and beans, and the quantity of rye and beans available is negligible. The production of barley and oats together, in 1916, was 28,000,000 quarters, and, including wheat, the

total quantity of bread corn produced was over 35,000,000 quarters. The quarter, however, is different in each case. Reduced to weight, 4½ quarters of wheat are equal to 5 quarters of barley, or to 7 quarters of oats. The proportion of each of these kinds of grain which is suitable for human consumption also differs considerably. In ordinary times about 70 per cent. of the wheat berry is extracted for flour but, as at the present time, 80 per cent. can be readily utilised for bread-making. The lower rate of extraction is, in fact, a comparatively recent innovation, made possible by the replacement of the old stone mills by the elaborate machinery of modern times, and stimulated by the irrational preference of the public for artificial whiteness in the loaf. The rates of flour extraction from barley and oats are however much lower.

The cultivation of oats in the United Kingdom has been maintained at about the same level for the past forty years, while the acreage of wheat, and in a less degree of barley, has declined. In the "'seventies," oats occupied about two-fifths of the total area under white corn crops, while for many years past the acreage under oats has been larger than the acreage under wheat and barley together. The new conditions of a guaranteed price for wheat and oats will affect the relative areas under the three crops, and it is difficult at present to estimate what the proportions in the future will be. It is probable, however, that any extension of wheat acreage will be accompanied by at least an equivalent addition to the acreage under oats. One probable result of

war experience will be to establish an increased consumption of oats as human food, though, on the other hand, the development of motor traction will reduce the demand for oats for horses. In any case, it is necessary, in making an estimate of increased self-sufficiency to take oats into account, although it must be noted that an acre of oats represents in potential breadstuffs only about three-fifths of the value of an acre of wheat.

The conclusion of the matter is that the new agricultural policy will materially improve the position of this country by reducing its dependence on imported wheat supplies but that the precise extent of the improvement cannot yet be calculated. It is earnestly to be hoped that the future will see not only a larger acreage under wheat, but also a substantial increase in the average yield, now that every corn-growing farmer can confidently incur, without serious risk of loss, the outlay necessary to obtain maximum crops from his land. If absolute security—in the sense that at any time of the year the country is entirely independent of oversea supplies—cannot be obtained by any increase of corn acreage which can reasonably be anticipated, there is a fair prospect that the anxieties of the past year as to the nation's food supply will in the future be very substantially diminished.

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